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The effect of periodic vehicle inspection on road traffic crash risk

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Abstract: In the European Union (EU), periodic inspection of motor vehicles is mandatory. In Denmark, cars and vans are inspected for the first time four years after the first registration and subsequently every two years, while lorries and buses are inspected annually. Denmark follows the EU minimum requirements, but there have been considerations to increase the frequency of inspections. However, based on previous research, the positive effects on crash risk are questionable. The aim of this study was to investigate the association between time since the most recent inspection and crash risk using nationwide Danish registry data. The hypothesis is that crash risk increases proportional with time since latest inspection. Methodologically, we used a case-control design. In total, 72 089 cars, 11 289 vans, 3 101 lorries and 1 575 buses involved in crashes were included as cases. Five controls were randomly selected per case and matched by age, brand and total weight. The analyses were controlled for odometer reading and the number of brake defects at the latest inspection. The study found no association between periodic inspections and crash risk in separate analyses of each vehicle type. There were no specific effects of inspections of older vehicles aged 10 years or more. This study does not provide evidence for expanding the current Danish inspection programme with more frequent checks of vehicles. The study also indicates that vehicles that are subject to the inspection programme are in good condition such that defects have a small (not negligible) impact on crash risk.

Keywords: buses, cars, crash risk, lorries, periodic inspection, road traffic safety, vans

1 Introduction

Every year, approximately 1 280 000 cars and vans are inspected in Denmark. These inspections cost Danish vehicle owners approximately 85.3 million euros annually. The good and relevant question is whether the periodic inspection system, mandated by common European Union (EU) legislation, has a direct impact on road traffic crash risk—that is, whether the crash risk decreases after the inspection and then successively increases with time since last inspection until a new check is due.

According to EU regulations, all cars and vans must undergo an initial inspection four years after the first registration and subsequent inspections every second year. Lorries and buses are to be inspected annually. These are minimum requirements, and in several countries, vehicles are inspected more often. The Danish inspection system is based on the minimum EU requirements.

1.1 Literature review

Six previous studies investigated the effect of vehicle inspection, and they have recently been analysed together in a systematic review (Martín-Delosreyes et al., 2021). The authors of the systematic review concluded that there is only a slight positive effect of periodic car inspection on crash risk but emphasised that methodological problems such as confounding bias and other weaknesses in study designs may have diluted any possible effects (Martín-Delosreyes et al., 2021). The next section reviews these studies in more detail.

Among the six studies, two were Norwegian investigations, both of which used crash data from insurance companies (Christensen & Elvik, 2007; Fosser, 1992). One study was a randomised controlled study from 1992 assessing the crash risk in 204 000 cars divided into three groups submitted to different inspection regimes (Fosser, 1992). One group was inspected annually, the second group only once during the study period of three years, and the last group was not checked at all. Fosser found no significant differences between the crash risk in the three groups (Fosser, 1992). Another more recent Norwegian study from 2007 included data on 253 000 cars and showed a slightly increased crash risk after an inspection compared to before the check of the car (Christensen & Elvik, 2007). However, this study also found that technical defects were associated with a minor increased crash risk. The insurance company crash data for this study were only available with a 30% coverage of the total car park, which may have influenced the results. An even older study conducted in New Zealand in 1986 was based on inspection and crash data from a smaller delimited area and found an immediate reduced crash risk after inspection, which gradually diminished over time (White, 1986). A US study, also from a period in which motor vehicle standards were much worse than today, found a 9% higher crash rate in cars that did not undergo inspection compared with cars that did attend an inspection programme (Schroer & Peyton, 1979). The authors also detected a 5% reduction in crash risk immediately after inspection in cars that were subject to an inspection programme, but differences in owner characteristics and car standards between the inspection and non-inspection groups may confound the result. The case-control study by Blows et al. (2003) found that crash risk was 2.7 times higher in the group of drivers hospitalised after a car crash without a valid inspection certificate This study is relatively small and may also suffer from recall and confounding bias (Blows et al., 2003). The last of the six studies on the direct effect of periodic inspection on crash risk was an investigation from 2013. It estimated an 8% reduction in crash risk through the replacement of an annual inspection programme with a semiannual scheme (Keall & Newstead, 2013). However, this effect was not statistically significant, and the authors concluded that it was outweighed by the economic cost of inspection paid by car owners.

1.2 Other studies on the impact of vehicle defects

A couple of studies have estimated the impact of vehicle defects. A British study found that defects were a contributory factor in 3% of all crashes. Furthermore, this study estimated that the number of vehicle defects increases with vehicle age and kilometres driven (Cuerden et al., 2011). Two US studies reported that 3% of all fatal crashes were fully or at least partially explained by vehicle effects (Das et al., 2019a,b). One of these studies compared states with and without mandatory periodic inspection and found no difference in fatal crash risk (Das et al., 2019b).

1.3 Heavy vehicles

The evidence concerning the effect of defects in heavy vehicles, such as lorries and buses, is scarce. However, an Australian study from 2018 showed that lorry drivers who are less concerned about attending periodic inspections of their vehicle are more likely to be involved in crashes that are at least partly explained by other driver-related contributory factors, such as fatigue, high speed, hazardous behaviour or driving under the influence of alcohol or drugs (Assemi & Hickman, 2018). The authors concluded that heavy vehicle defects have a small impact on overall crash risk, but it should be noted that lorries do 8% of the transport work while involved in 18% of fatal crashes or crashes with serious injury in Australia.

1.4 Evaluation of alternative inspection regimes

As mentioned above, the Danish inspection programme follows the minimum EU requirements through the so-called 4-2-2-2 regime for cars and vans. Lorries and buses must be inspected every year. Although other regimes have been assessed, such as the 4-2-1-1 regime (with annual inspections after year six for cars and vans), in macro evaluations and cost–benefit analyses, the overall results are uncertain, and effects relatively small (Berntoft & Pilegaard, 2012; CITA, 2010; Cuerden et al., 2011; Keall & Newstead, 2013; Stipdonk & Bos, 2015). Some of these analyses included the effects on emissions and fuel consumption in addition to crash risk, which is a clear advantage (CITA, 2010; Berntoft & Pilegaard, 2012).

1.5 Study aim

In addition to the older Norwegian studies, the evidence on the direct effect of periodic inspection on crash risk is limited, as documented in the systematic review from 2021 (Martín-Delosreyes et al., 2021). Effect estimates of the current inspection programme are lacking, and currently, decisions are based on sparse data with no direct correlation between inspection and crash data on individual vehicles.

The aim of this study is to provide new evidence to assess the effect of the current periodic inspection programme on the actual crash risk in cars, vans, lorries and buses.

1.6 Hypotheses

Based on the literature and preliminary analyses performed on Danish inspection data, we propose the following hypotheses before merging inspection data with the crash data:

- We expect the periodic inspection programme to have an effect on crash risk, which occurs through the repair of defects and the exchange of parts, such as brake pads and discs, in the period before an inspection. This behaviour implies a decrease in crash risk immediately after the inspection, as depicted in Figure 1, whereafter the crash risk gradually increases until just before a new inspection is scheduled.
- We hypothesise that the effect of inspection will be especially large for older cars.
- We expect an effect of vehicle age/odometer reading on crash risk.
- We hypothesise that the number of brake defects found affects crash risk because of bad maintenance or the vehicle being 'worn out'.

2 Methodology

Data on all conducted vehicle inspections in Denmark from the period between 1 January 2005, and 31 March 2018, were obtained from the Danish Road Traffic Authority. Data on police-reported road traffic crashes, both with personal injury and material damage, from 2009 to 2017 originated from the Danish Road Directorate. The crash data were not complete because for some crashes, probably the lightest cases, the police did not report all of the involved licence plates. The coverage was approximately 70%. Furthermore, we obtained data on vehicle populations, that is, all registered motor vehicles, available in May each year from 2008 to 2017. The crash data comprise information on licence plates, while the vehicle inspection and population data comprise information on both licence plates and the Vehicle Identification number (VIN) of each vehicle. Therefore, a merger of crash, inspection and population data was possible. We chose to match the vehicles involved in crashes to the VIN code closest backwards in time, whereas vehicles that disappeared from the population between two years were left out of the analysis from 1 June in the year in which the vehicle was registered for the last time. Disappearance could be due to total damage or other reasons for VIN number deletion from the population registry.

Figure 1 Hypothesised association between vehicle age, scheduled inspection times according to the 4-2-2-2 programme in Denmark for cars/vans and the actual crash risk, which is drawn with solid lines and 'dents'.The dashed line illustrates the increase in crash risk with the age of the vehicle. The actual crash risk drops after each inspection and thereafter gradually increases during the next two years until a new inspection is scheduled.

For the statistical analyses of cars, vans, lorries and buses, we used a matched case-control design. Cases were vehicles involved in all types of crashes, without restriction to crashes due to vehicle defects, because the Danish crash data do not include contributory factors. For each case vehicle, we randomly selected five controls present in the population on the crash date of the case. The controls had not been involved in crashes before the crash date of the case. The match of cases to controls was done with regard to the following factors: age (in one-year intervals), brand and total weight (appropriately chosen weight intervals, e.g. 250 kilogram intervals for cars). Regarding the exposure, that is, the inspection status on the crash date of the case, we divided the time since the latest inspection into categories (0–90 days, 91–182 days, 183–365 days, 1–1.5 years and 1.5–2 years), as depicted in Figure 2 . We assumed that vehicles in the exposure category '1.5–2 years' were close to the standard of vehicles in the category '0–90 days' because owners were encouraged to fix defects just before scheduled inspections. Crash risk in the different exposure categories can be compared to assess whether specific intervals between two inspections are accompanied by increased risk, thus allowing us to investigate our key hypothesis. The exposure variable for the analyses of lorries and buses was also divided into categories (0–90 days, 91–182 days and 183–365 days) but only up to a maximum of one year since the latest inspection since heavy vehicles are inspected annually.

The estimation of odds ratios for the comparison of crash risk in the different categories based on the exposure variable (time since latest inspection) took place using conditional logistic regression (Clayton & Hills, 1993). Odds ratios can be interpreted as risk ratios because the crash risk is relatively small. All analyses were controlled for odometer reading (in categories according to quintiles) and the number of brake defects found in the latest inspection (0, 1, 2 or 3+ defects). Because we focused on the effect of the current inspection programme, we excluded all vehicles that had not yet been inspected from the analysis. Additionally, we included only cases and controls that were subject to the scheduled inspection programme. Furthermore, we restricted the analysis to vehicles not older than 20 years. To address whether vehicle age modifies the effect of periodic inspection on crash risk, we tested whether the interaction between a dummy indicating whether the vehicle age was above 10 years and the categorical variable time since latest inspection was statistically significant.

A significance level of five percent was chosen. We supplied the estimated odds ratios with 95% confidence intervals.

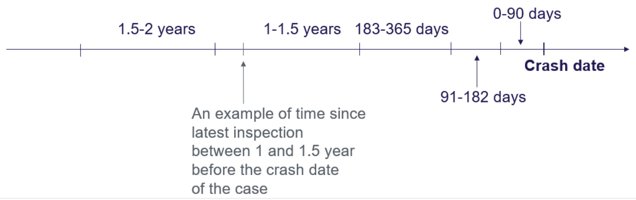

Figure 2 The exposure variable (time since latest inspection) was divided into categories to allow us to assess the hypothesis of increasing crash risk with time since inspection.

3 Results

We had data on 125 182 cars, vans, lorries and buses involved in crashes in the period of 2009–2017. Restricting the cases to vehicles that were below 20 years old and inspected at least once, the analyses were based on 72 089 case-cars, 11 239 case-vans, 3 101 case-lorries and 1 575 case-buses. Five controls per case matched on age, brand and total weight were selected. A few cases with fewer than five controls were included when it was not possible to find five. The analyses were conducted separately for each type of four-wheeled motor vehicle.

3.1 Cars

Table 1 displays the crude distributions of time since latest inspection, odometer readingand number of brake defects. The variable of primary interest, time since latest inspection, was equally distributed between cases and controls, as was the variable number of brake defects. In contrast, for odometer reading at the latest inspection, the proportion of cars involved in crashes increases by kilometres driven. Regarding the matching variables, there was fine compliance between cases and controls (results are not shown because the space is limited).

Table 1 also shows the estimated effects of time since latest inspection on crash risk. We found no statistically significant effects (p-value = 0.43) and thus no statistically significant increased crash risk with time since the most recent inspection. However, for odometer reading, we noticed a clear statistically significant increasing trend of crash risk with number of kilometres driven (p-value < 0.0001). Regarding the number of brake defects, crash risk tended to increase with the number of defects (p-value = 0.09), however not in the 3+ category, because few cars (0.1%) display this many defects at inspections.

Table 1 Estimated odds ratios in the analysis of the effect of periodic inspection on crash risk in cars

	% cases (N = 72 039)	% controls (N = 353 733)	Odds ratio	95% confidence interval	p-value
Time since latest inspection					
0–90 days	14.0	13.5	1.00 (ref)		0.43
90–182 days	13.8	13.4	1.03	1.00–1.06	
83–365 days	26.4	26.3	1.02	0.99–1.05	
1-1.5–years	24.4	24.9	1.02	0.99–1.05	
1.5–2 years	21.3	22.0	1.02	0.99–1.05	
Odometer reading in km					
0–85 000	18.0	20.3	1.00 (ref)		< 0.0001
86 000–135 000	19.4	20.7	1.18	1.15–1.22	
136 000–185 000	19.8	20.1	1.38	1.33–1.42	
186 000–246 000	21.2	19.9	1.59	1.54–1.64	
247 000+	21.6	18.9	1.81	1.75–1.87	
Number of brake defects					
0	97.9	98.1	1.00 (ref)		0.09
1	1.7	1.6	1.06	1.00–1.13	
2	0.3	0.3	1.15	0.98–1.34	
3+	0.1	0.1	0.97	0.75–1.26	

The hypothesis was that crash risk increases with time since latest inspection. The analysis was controlled for odometer reading and number of brake defects at the latest inspection. Controls were matched to cases by production year, brand and total weight.

We noticed two marginally statistically significant results in single odds ratio estimates. The difference in crash risk between the 90–182 days and 0–90 days categories was marginally statistically significant (p-value = 0.07). An increased crash risk was also observed when a car had one brake defect compared with no brake defects (p-value = 0.06). Finally, we investigated whether a car age higher than ten years modified the effect estimates regarding time since latest inspection, and we found that it did not (p-value = 0.66).

3.2 Vans

In Table 2, we report the results of the analysis of vans. Similar to cars, the variables time since the latest inspection and number of brake defects display very equal distributions in cases and controls, whereas the distribution of odometer reading exhibits higher percentages among cases than controls, thus indicating an increasing crash risk with the number of kilometres driven. The latter finding was substantiated in the estimation of odds ratios (p-value < 0.0001). On the contrary, we did not observe any effect of time since the latest inspection of the vans from the estimated odds ratios (p-value = 0.64) or the number of brake defects (p-value = 0.71).

We investigated whether an age of 10 years and above had a separate effect of periodic inspection, but found that it did not (p-value = 0.65).

3.3 Lorries

Regarding lorries and the effect of annual periodic inspections, Table 3 shows the distributions of time since the most recent inspection, odometer reading and total number of brake defects in cases and controls for comparison. Similar to cars and vans, only odometer reading exhibits differences in the distributions of cases and controls. The estimation of odds ratios reveals no effect of periodic inspection on crash risk (p-value = 0.39), because there was no statistically significant difference between any of the time periods since latest inspection. No effect of the number of brake defects was seen either, while an increasing trend by the number of kilometres driven was observed.

In our data, we saw no distinct effect of periodic inspections in older lorries above the age of 10 years (p-value = 0.15).

Table 2 Estimated odds ratios from the analysis of the effect of periodic inspection on the crash risk of vans

	% cases (N = 11 239)	% controls (N = 54 847)	Odds ratio	95% confidence interval	p-value
Time since latest inspection					
0–90 days	14.3	13.9	1.00 (ref)		0.64
90–182 days	14.2	13.8	1.03	0.96–1.12	
183–365 days	26.7	26.2	1.04	0.97–1.12	
1-1.5–years	23.7	24.5	1.00	0.93–1.08	
1.5–2 years	21.1	21.7	1.02	0.94–1.09	
Odometer reading in km					
0–85 000	18.3	20.3	1.00 (ref)		< 0.0001
6 000–135 000	18.8	20.7	1.14	1.06–1.22	
36 000–185 000	19.8	20.4	1.30	1.21–1.40	
186 000–246 000	21.2	20.0	1.49	1.38–1.61	
247 000+	22.0	18.6	1.78	1.64–1.93	
Number of brake defects					
0	98.0	97.9	1.00 (ref)		0.71
1	1.7	1.7	0.96	0.82–1.13	
2	0.2	0.3	0.81	0.54–1.23	
3+	0.1	0.1	0.87	0.46–1.66	

The statistical analysis controlled for odometer reading and number of brake defects at the latest inspection. Controls were matched to cases by production year, brand and total weight.

Table 3 Estimated odds ratios from the analysis of the effect of periodic inspection on the crash risk of lorries

	% cases (N = 3 101)	% controls (N = 15 289)	Odds ratio	95% confidence interval	p-value
Time since latest inspection					
0–90 days	26.9	26.8	1.00 (ref)		0.39
90–182 days	27.4	26.3	1.08	0.97–1.20	
183–365 days	45.8	46.9	1.04	0.94–1.14	
Odometer reading in km					
0–105 000	16.9	20.7	1.00 (ref)		< 0.0001
106 000–206 000	18.9	20.2	1.28	1.12–1.47	
207 000–334 000	19.6	19.9	1.51	1.30–1.75	
35 000–517 000	21.4	19.9	1.80	1.54–2.10	
518 000+	23.3	19.3	2.21	1.88–2.61	
Number of brake defects					
0	97.9	98.0	1.00 (ref)		0.67
1	1.8	1.7	1.04	0.77–1.40	
2	0.2	0.2	0.81	0.34–1.94	
3+	0.1	0.1	1.99	0.60–6.62	

The statistical analysis controlled for odometer reading and number of brake defects at the latest inspection. Controls were matched to cases by production year, brand and total weight.

3.4 Buses

Lastly, we report the results of our calculations on buses in Table 4. We found no effect of annual periodic inspections on crash risk, as can be seen from the estimation of odds ratios (p-value = 0.68). There was no effect of the number of brake defects on crash risk (p-value = 0.91), whereas crash risk increased with the number of kilometres driven in a bus (p-value = 0.03).

No distinct effect of periodic inspections in older lorries above the age of 10 years was observed (p-value = 0.65).

4 Discussion

This study cannot demonstrate an effect of periodic inspection in Denmark, neither for cars, vans, trucks or buses with the current inspection schemes, but the study shows that mileage has an effect on crash risk. Thus, the 'dents' illustrating the effect of the inspection programme in cars in Figure 1 cannot be shown to exist. Therefore, the study cannot be used as an argument in favour of extending the current inspection programme in Denmark with more frequent checks. For cars, however, we reported a nearly statistically significant increased crash risk of 3% when there were between three and six months since the most recent inspection compared with newly inspected cars (p = 0.06) which could suggest a small (but not negligible) impact of periodic inspection on the crash risk. As mentioned above, this study clearly detects an impact of exposure (mileage) on the crash risk. We matched case and control vehicles by vehicle age and therefore the odds ratio estimates regarding mileage compare vehicles of the same age but with different odometer readings thus corroborating that exposure matters as expected from the traffic safety theory.

4.1 Comparison with other studies

The study thus corroborates the findings of the systematic review from 2021, which identified six previous relatively old studies on the subject (Martín-Delosreyes et al., 2021). The review by Martín-Delosreyes et al. (2021) concluded that periodic inspection had a marginal positive effect; however, this effect was likely overestimated due to methodological problems. In Denmark, cars and vans must be inspected according to the 4-2-2-2 scheme, under which vehicles are inspected for the first time after four years and subsequently every second year. Lorries and buses must be inspected annually. A Danish cost-benefit analysis estimated that it would not be beneficial to change to a 4-2-1-1 regime in an economic statement of the pooled effects on crashes, emissions and fuel. The 4-2-1-1 scheme would require cars and vans to be inspected for the first time after four years, then at the age of 6 years and annually thereafter. However, a significant problem in such macro-level analyses is the presence of substantial uncertainties, as reviewed by Berntoft & Pilegaard (2012). The literature is permeated by uncertainties and relatively small studies with design 'beauty defects', which, as mentioned above, may explain past positive effects of periodic inspection on crash risk. Several authors have conducted macro comparisons of the aggregated number of vehicle defects with aggregated crash risk estimates. In summary, these studies agree that defects in contemporary motor vehicles only modestly act as contributory factors in approximately 3% of crashes (Cuerden et al., 2011; Das et al., 2019b,a). This supports the results of this study, which cannot find evidence that checking motor vehicles for defects has a large effect on crash risk. Regarding heavy vehicles, other circumstances may apply, as one Australian study mentioned that heavy vehicles are involved in 18% of all fatal and serious traffic crashes in the country while only accounting for 8% of the traffic volume (Assemi & Hickman, 2018). Contributory factors other than defects could be at play, such ai inattention or other driver-related factors. At the same time, Denmark is a small country and therefore the number of heavy vehicles and accidents involving them in our dataset is limited. However, on the basis of these data, we did not see any effect of periodic inspection on crash risk in heavy vehicles.

We evaluated the statistical power of our study of cars and found it sufficient for the detection of a positive effect of periodic inspection of 3%. In other words, for cars, we were not able to find smaller effects of periodic inspection with enough power. We detected a marginally statistically significant increased risk of 3% in the period 90–182 days since the most recent inspection and no effect in the other categories. This increased risk means that there may be a period when the crash risk is higher. The statistical power in the studies of vans, lorries and buses was lower and therefore cannot be used to draw any reliable conclusions concerning the influence of inspection on crash risk for these groups. However, our study can be included in future meta-analyses on the

Table 4 The estimated odds ratios from the analysis of the effect of periodic inspection on the crash risk of buses

	% cases (N = 1 575)	% controls (N = 7 678)	Odds ratio	95% confidence interval	p-value
Time since latest inspection					
0–90 days	27.4	26.3	1.00 (ref)		0.68
90–182 days	6.5	26.7	0.94	0.80–1.11	
183–365 days	6.1	47.0	0.94	0.81–1.09	
Odometer reading in km					
0–105 000	19.1	20.4	1.00 (ref)		0.03
106 000–206 000	19.6	20.1	1.17	0.92–1.49	
207 000–334 000	20.4	19.9	1.34	1.03–1.73	
335 000–517 000	19.6	20.1	1.33	1.01–1.76	
8 000+	21.3	19.5	1.58	1.19–2.11	
Number of brake defects					
0	98.2	98.2	1.00 (ref)		0.91
1	1.6	1.6	0.99	0.63–1.56	
2	0.1	0.2	0.62	0.14–2.75	
3+	0.1	0.1	0.66	0.08–5.59	

The statistical analysis controlled for odometer reading and the number of brake defects at the most recent inspection. Controls were matched to cases by production year, brand and total weight.

effect of periodic inspection together with international evidence. Comparing with the literature, our study is larger than other studies.

4.2 Possibilities and limitations of the study

A clear advantage of this study is its considerable statistical power, especially for cars. The data comprise all cars, vans, lorries and buses in Denmark between 2009 and 2017, implying limited selection problems because VIN numbers were only missing when they were both registered and deregistered within one year between two updates of the vehicle population registry. However, it must be noted that these vehicles could be missing because of total damage after a crash. This very limited problem could have provided more cases and higher precision of estimates but did not lead to an underestimation of the effect of periodic inspection on crash risk.

The study lacks controls for driver-related factors, such as sex, age and socioeconomic status, which are known to be associated with crash risk. We could not keep track of owner shifts either. Shifts could potentially influence the car standard and frequency of service checks and thus confound the results, along with driver-related factors. However, we claim that these shifts and factors are not associated with the time since the latest inspection variable because cars are bought, registered and thus placed in the inspection scheme independent of driver characteristics. On this basis, we exclude effect underestimation.

One limitation of this study is underreporting of crash data. This means that there can be vehicles in the control group that have been in a crash, but where the crash is not registered. The true number of unreported vehicle crashes is unknown, but in Denmark there are 3.3 million vehicles and around 14 000 road traffic crashes per year are registered by the police which form the basis for this study. So, even with a significant larger number of unreported accidents, it seems unlikely that this source of error is significant. The same source of error was present in the two Norwegian studies that used incomplete crash data from an insurance company (Christensen & Elvik, 2007; Fosser, 1992).

4.3 Implications

Based on this study, there is no clear evidence for extending the Danish inspection programme to more frequent checks of cars and vans. This study may suggest a small, however not negligible, effect on crash risk due to vehicle defects in cars and vans.

There are, however, other positive effects of periodic inspection. Today, vehicle exhaust and thus emissions are also checked. These effects were not assessed in our study. A future safety-related topic for inspection programme could include checks of advanced electronics in modern motor vehicles. Electronic systems, such as lane assistance and automatic emergency braking, should ensure better road traffic safety but could deteriorate with vehicle age.

This study specifically evaluated the effect of the inspection of older vehicles above the age of ten years and found no evidence for a statistically significant increased crash risk in cars, vans, lorries or buses. Further studies of the inspection data from the Danish Road Traffic Authority uncovered that the number of defects increases with vehicle age. A finding, which is corroborated in the literature, thus suggesting that older vehicles must undergo extra inspection. Cuerden et al. (2011) suggested that motor vehicles should be inspected based on kilometres driven and not vehicle age, whereas a Dutch study found that annual inspections after an odometer reading of 160 000 km had a positive effect on road traffic safety (Stipdonk & Bos, 2015). This study found a clear increase in crash risk with the number of kilometres driven for all four vehicle types, but since the study did not account for other confounding factors such as owner age, this cannot be used to determine whether vehicles should be inspected based on odometer readings.

5 Conclusion

This study did not find evidence of an increase in crash risk with time since the most recent inspection for cars, vans, lorries and buses. Therefore, a hypothesis of fewer crashes with more frequent inspection could not be confirmed in Denmark, where the minimum requirements of inspection decided by the European Union have been adopted. Minimum requirements where cars and vans are inspected for the first time at four years after first registration and every second year subsequently, whereas lorries and buses are inspected annually. For cars and vans, the study may suggest effects of vehicle defects of size smaller than 3% - small but not negligible. Finally, this study found a clear increase in the crash risk by mileage for all vehicle types.

CRediT contribution statement

Anne Vingaard Olesen: Conceptualization, Data curation, Formal analysis, Funding acquisition, Visualization, Writing—original draft. **Harry Lahrmann:** Conceptualization, Writing—review & editing. **Laura Vangsgaard Jensen:** Writing—review & editing. **Rasmus Øhlenschlæger:** Conceptualization, Data curation, Funding acquisition, Writing—review & editing.

Declaration of competing interests

The authors have nothing to declare.

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