Heavy vehicle wheel detachment: Frequency of occurrence, current best practice, and potential solutions

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Executive summary

When a wheel becomes detached from a heavy vehicle it may simply come to rest without causing any further damage or harm. However, in the wrong circumstances, it can collide with other vehicles or road users and cause an accident and, in some cases, this has resulted in fatalities. Typically, it is only the more serious accidents that occur as a result of wheel detachment that are identified by standard reporting mechanisms. Such detachment of wheels from vehicles, particularly heavy commercial vehicles, has been a cause of concern for many years and there has been a considerable amount of investigative work and comment on the subject. In 1997, the Department for Transport (DfT) published an advice leaflet ("Careless Torque Costs Lives") with the intention of reducing the scale of the problem. Despite this previous research, comment and advice, there is evidence to suggest that wheel detachment still occurs. There is, therefore, a need to more accurately quantify the current frequency of wheel fixing problems and to assess current practices within the industry in order to assess whether the previous advice has had a beneficial effect and to identify new action that could be taken to reduce the scale of the problem. The research was funded by the DfT and this report describes all of the work undertaken and the results and conclusions drawn from it.

The work involved:

- A survey run by VOSA and ACPO to investigate the current frequency of wheel fixing problems in the UK
- Studying existing sources of data on wheel fixing problems.
- Obtaining information from other countries to assess the scale of the problem in the EU and elsewhere
- Carrying out a survey of heavy vehicle drivers, operators and manufacturers in order to gain their views and perceptions
- Review current standards related to wheel fixings and procedures for wheel nut tightening.

The main findings were as follows:

- The various studies carried out produced quite variable estimates of the frequency of wheel fixing problems. However, with the exception of the TRL driver survey, there was general agreement that the frequency of loose or missing wheel nuts is in the low thousands each year, the frequency of wheel detachment is in the low hundreds each year and that annual fatalities resulting from wheel detachment are likely to be in single figures.
- Based on the data and a range of assumptions about the data, TRL has estimated that the typical annual frequency of wheel fixing problems is between 7,500 and 11,000 wheel fixing defects resulting in between 150 and 400 wheel detachments. Of the wheel detachments, it was estimated that between 50 and 134 would result in damage only accidents, 10 to 27 in injury accidents and 3 to 7 in fatal accidents.
- It was not possible to reliably determine whether the frequency of occurrence has changed since 1997 and the publication of "Careless Torque". There was some evidence to suggest that the frequency had decreased but there was also some conflicting evidence that it had stayed constant or increased.
- Requests for data on wheel fixing problems were sent to a wide variety of countries. There is sufficient evidence of wheel fixing problems to state confidently that this problem is not unique to the UK. There was insufficient detailed information to enable an accurate comparison with the estimated frequency of occurrence in the UK but there was sufficient evidence to suggest that the levels are "broadly comparable".
- There is a bias toward problems occurring on the nearside of vehicles (i.e. left in the UK). However, this bias is small for loose wheel nuts but large for wheel detachments suggesting it may be of small influence in the root cause of nut loosening but may have a larger influence on the rate of progress between the first nut loosening and full wheel detachment.

- Findings in Finland showed that there is a strong bias toward wheels becoming detached from the left side of vehicles, the same as in the UK, despite the fact that they travel on the opposite side of the road. This lends support to the theory that the direction of wheel rotation in relation to thread direction could have an influence on how quickly a loose wheel nut turns into a full wheel detachment.
- There has been a considerable amount of research into the mechanics of wheel nut loosening and the causes are now well understood. Clamp load is considered the main parameter and the clamp load must be sufficiently high to withstand all applied forces despite any effects of joint relaxation, variation in the torque to clamp ratio, relaxation due to temperature. However, this must be achieved without the clamp force being so high that the yield point of the stud is exceeded.
- Current designs of wheel fixing are capable of achieving this providing joint relaxation is accounted for with re-torquing and all components are in very good condition. However, the factor of safety allowed means that considerable maintenance of the joint is required to maintain its effectiveness over several years' service, particularly where vehicles are exposed to harsh operating environments.
- A wide range of best practice guidelines are available that recommend practice and procedures for fitting and maintaining wheels. In general the research into wheel fixing problems has meant that many of the requirements are now common to all of them but there are still areas such as actual torque levels and the issue of lubrication where there is no standard approach. Further development towards common standards may well be beneficial.
- Although most operators (86%) reported that they do have formal policies and procedures in place regarding wheel fixings, the survey showed evidence to suggest that these were not always in accordance with the guidelines discussed above. For example 12% of operators reported "never" re-torquing a wheel after it has been refitted.
- Similarly, there was strong evidence that a large proportion of drivers did not understand and/or adhere to the best practice requirements. For example, despite all operators stating that drivers should conduct a daily visual inspection, 26% of drivers admitted not always doing this and 32% admitted not always looking for signs of loose wheel nuts. Two percent admitted to "never" carrying out daily visual checks.
- The surveys also showed that there was evidence to suggest that those drivers or operators who better understood and adhered to the requirements reported a lower incidence of wheel fixing problems.
- It can, therefore, be seen that maintenance is a key issue for the current design of wheel fixing. The theory shows why it is important in physical terms, there are a range of guidelines in existence, there is evidence to show that these guidelines are not always followed and evidence to show those that do follow them report lower levels of wheel fixing problems.
- A range of potential measures capable of reducing the frequency of occurrence or mitigating the consequences were identified. These range from indicators of wheel nut movement to a complete redesign of wheel fixing methods. The physical effectiveness of these potential solutions was not evaluated but the survey showed that they were generally perceived to be beneficial by the industry. However, 2% of the defects found in the VOSA survey were found on vehicles equipped with wheel nut retention devices and 15% were found on wheels fitted with movement indicators. This shows that adding these devices alone will not eliminate the problem, although it may well reduce it, and good maintenance practice will still be required.
- A substantial difference was found between the perceived importance of wheel fixing problems in relation to other heavy vehicle safety issues and the relative importance in terms of fatal accident statistics. The industry respondents considered wheel fixing problems as second only to collisions with other vehicles. However, fatal accident statistics showed that wheel detachment contributed to 0.57% of fatal accidents whereas about three-quarters of

fatalities in accidents involving HGVs involved collisions between vehicles, 17% involved collisions with pedestrians and approximately 3% involved contributory brake defects.

The report recommended that consideration was given to routinely monitoring the frequency of wheel fixing problems, possibly through the use of the VOSA prohibitions database combined with detailed exposure data. It also recommended that consideration be given to further work to investigate improvements such as:

- Further standardisation of best practice wheel tightening procedures, in particular, simplifying the identification of recommended torque settings and standardising on the use of lubrication.
- Further education and or enforcement to encourage universal adoption of rigorous wheel maintenance procedures.
- The possibility of a fundamental re-design of the method of wheel attachment for heavy vehicles to produce a much lower maintenance solution.
- The potential mandatory use of wheel nut retention devices or movement indicators, if independently shown to be effective.

1 Introduction

When a wheel becomes detached from a heavy vehicle it may simply come to rest without causing any further damage or harm. However, in the wrong circumstances, it can collide with other vehicles or road users and cause an accident and, in some cases, this has resulted in fatalities. Typically, it is only the more serious accidents that occur as a result of wheel detachment that are identified by standard reporting mechanisms. Such detachment of wheels from vehicles, particularly heavy commercial vehicles, has been a cause of concern for many years and there has been a considerable amount of investigative work and comment on the subject. In 1997, the Department for Transport (DfT) published an advice leaflet ("Careless Torque Costs Lives") with the intention of reducing the scale of the problem. Despite this previous research, comment and advice, there is evidence to suggest that wheel detachment still occurs. There is, therefore, a need to more accurately quantify the current frequency of wheel fixing problems and to assess current practices within the industry in order to assess whether the previous advice has had a beneficial effect and to identify new action that could be taken to reduce the scale of the problem.

The objectives of this research project were to:

- Identify the current frequency of wheel detachment in the UK and analyse the trend over time. This involved carrying out a survey with the Vehicle Operator and Services Agency (VOSA) and the Association of Chief Police Officers (ACPO), comparable to the one conducted in 1997 (DETR, 1998), as well as reviewing existing accident and defect databases.
- Gather parallel information on the scale of the wheel detachment problem in other EU Member States.
- Survey the views of heavy vehicle drivers, operators (including wheel and tyre maintenance contractors), and manufacturers (of vehicles, wheel fixings and wheel nut retention/indication devices) with respect to heavy vehicle wheel detachment, locking wheel nuts/studs, and nut movement indication devices.
- Identify current wheel fixing standards and current best practice in wheel nut/stud tightening methods.
- Provide a preliminary cost benefit analysis for improving the situation, including the possibility of equipping the UK heavy vehicle fleet with wheel locking and indication devices.

The research was funded by the DfT and this report describes all of the work undertaken and the results and conclusions drawn from it. A large quantity of information was found and for this reason the main body of this report contains only a summary of the results, which are fully reported in the appendices.

2 Research methods

2.1 VOSA/ACPO Frequency survey

To establish the current frequency of wheel detachment and loose wheel fixings, surveys were carried out throughout Great Britain by VOSA (formerly VI) and the Association of Chief Police Officers (ACPO). Both surveys were three months in duration. The VOSA survey started in November 2005 and finished at the end of January 2006. The ACPO survey started in January 2006 and finished at the end of March 2006.

Capture forms were designed by TRL to gather the following information:

- Inspection or accident and injury details
- Vehicle details, including vehicle type, gross weight, age, wheel size and configuration
- Defect details, including type of defect, number of defects and position on vehicle
- The presence of any locking mechanism or movement indicators
- The date of last wheel removal, re-torque or torque check

Consideration was given to the type of information recorded during the VI and ACPO survey carried out during 1997 (DETR, 1998) so that the current data could be compared with the previous study.

VOSA was tasked with examining vehicles at operators' premises and carrying out roadside spot checks as well as attending post-collision vehicle examinations and reporting the above information for all examinations that concerned a wheel defect.

Similarly, ACPO were asked to distribute the data capture form to all of their officers involved in collision investigation such that any heavy vehicles with wheel defects that were examined as part of an investigation were reported.

In order to scale up the number of observed failures to an estimate of annual incidents in the UK, an estimate of the typical number of vehicles examined by VOSA each year was combined with the number of vehicles registered in each year as a measure of exposure.

The data was compiled into a database and analysed to produce national estimates of the scale of the problem and to identify any common features. The results of the VOSA and ACPO surveys are summarised in section 3.

2.2 Analysis of existing UK data

The following data sources were analysed to provide historical information on the wheel detachment and loose wheel fixings problem.

- Institute of Road Transport Engineers (IRTE) survey (IRTE, 1986, now SOE)
- VOSA/ACPO survey (DETR, 1998)
- The VOSA prohibitions database
- The VOSA collisions database
- The Heavy Vehicle Crash Injury Study (HVCIS) fatals database

The IRTE carried out an extensive investigation of wheel nut loosening and possible solutions to it which included some information related to the frequency of occurrence. This frequency information is reviewed in this section.

In 1997, the DfT asked VOSA and ACPO to carry out a survey of the frequency of occurrence of loose wheel nuts. The method used for this survey was that every time a VOSA or Police vehicle examiner examined a vehicle with a loose wheel fixing or detached wheel they would complete a form describing the event. These forms were then collated nationally and compiled into a database for analysis.

VOSA examine about 20% of all heavy vehicles each year in road side inspections. Whenever a serious defect is found, they have the power to issue a prohibition order that prevents the vehicle from being used on the road until the problem is rectified. Loose wheel fixings are one of the many items that can result in a prohibition being issued. All prohibitions are recorded on a database and, as such, this has the potential to offer information on the loose wheel nuts problem.

When an accident involving a heavy vehicle occurs, the Police will often ask a VOSA vehicle examiner to inspect the vehicle in order to identify whether any vehicle defects may have contributed to the cause of the accident. Every time a VOSA examiner attends an accident for this purpose, he or she completes a form for entry onto the VOSA collisions database. Because entry onto this database depends on the police asking for VOSA assistance, the data does tend to be skewed to more serious accidents and for the same reason it cannot be considered representative of the UK as a whole. It is, therefore, difficult to make confident estimates of the overall level of occurrence from this data but it is possible to look at trends over time and the distribution of events in relation to other vehicle features.

The database was substantially redeveloped in the late 1990s and early 2000s. There were, therefore, two separate data sets available for analysis, the first covering a period from 1992 to 1996 and the second covering a period from January 2003 to August 2004.

The Heavy Vehicle Crash Injury Study is a project carried out by TRL and funded by the DfT to collect information on accidents involving heavy vehicles. One of the main parts of this project is the collection and coding of police fatal accident reports onto a database. For heavy goods vehicles, comparable data has been collected from 1988 to 2002, although fewer cases are available for the more recent years. In general, TRL collects between one and two thirds of all police fatal accident reports where heavy vehicles are involved, thus generating a comprehensive and representative database. The project is focussed on vehicle issues in accidents and contains a considerable amount of vehicle data, including a field that identifies whether preventing wheel detachment would have prevented an accident from occurring.

2.3 Review of frequency in other countries

It was not considered feasible to carry out a live survey of specific new data in other EU states within the timetable allocated for this work. Therefore, TRL contacted enforcement authorities and other organisations within the EU to request information regarding wheel detachment and loose wheel fixings.

A letter was prepared and circulated to a number of organisations, the letter was also circulated by the CITA (European association of vehicle inspection organisations) to its members with a request that they send any information that they may have. Responses were received from representatives from both within the EU and also outside the EU, from countries such as Japan, New Zealand and the Ivory Coast.

2.4 Survey of heavy vehicle drivers, operators, manufacturers and component suppliers

Questionnaire surveys were carried out of drivers, operators and manufacturers/component suppliers to get both factual information about incident frequency and maintenance practices (including methods of wheel tightening/re-torquing) and also perceptions about the causes, costs and possible solutions of the wheel loss problem. The questionnaires were designed and developed specifically for this project.

The drivers' questionnaire, which was created first, was piloted amongst drivers attending truck simulator training in Scotland, modified slightly and finalised for use. The target was to obtain 500 completed driver questionnaires in a number of surveys in a variety of locations.

The operator and manufacturer/component supplier questionnaires were developed from the drivers' questionnaire utilising many of the drivers' questions but adding other questions appropriate to the respondents' roles. The aim was to obtain 30 completed questionnaires from both operators and manufacturers/component suppliers.

An agreement had been made with VOSA to interview drivers at one or more of their enforcement sites. Although some interviewing took place at their Dagenham site, it was not found to be wholly satisfactory because the drivers were sometimes interrupted while filling in their questionnaires by the VOSA inspector requiring information about, or movement of, their vehicle. In addition, it was thought that drivers might not be willing to disclose any wheel fixing problems that they had encountered because they were being interviewed on an enforcement site (despite the fact that they were told the questionnaires formed part of a research project).

In order to overcome these drawbacks, it was decided to try to interview drivers in more "neutral" locations including at a Motorway service area if permission to do this could be obtained. This was arranged with the retail manager of the Fleet Service Area on the M3 motorway and interviewing of London-bound drivers took place there on 5 days in December 2005 and 1 day in January 2006.

The other major source of questionnaires was through TRL's Scottish Truck Simulator (ScotSim) operation – some of these questionnaires were obtained via Scottish operators and others by interviewing westbound drivers at the Harthill Service Area located between junctions 4 & 5 on the Edinburgh to Glasgow M8 motorway. The final source of driver questionnaires was via English vehicle operators involved in the operator survey. Table 1 summarises the numbers & sources of the driver questionnaires.

Table 1. Numbers and sources of the driver questionnaires

Dates	Number	Source	Location
18 to 24 Nov 05	75	VOSA	Dagenham
15 to 22 Dec 05 and 5 Jan 06	335	M3 Service Area (London bound)	Fleet, Hampshire
Dec 05/Jan 06	11	English HV Operators	Southern England
Dec 05/Jan 06	83	M8 Service Area (Westbound)	Harthill (between Edinburgh & Glasgow)
Dec 05/Jan 06	17	Scottish HV Operators	Scotland
Nov 05 to Jan 06	521	All sources	UK

It was considered that this coverage of drivers was suitably broad & varied for the purposes of the survey.

The target of the operator survey was to obtain 30 completed questionnaires from heavy vehicle operators including those operating goods vehicles and those operating coaches/buses. A variety of firms was required both in terms of distances travelled and commodities carried.

A number of firms offered to take part in the survey having seen TRL's September 2005 Press Release. Some were keen to share their experiences of wheel fixing problems and, in some cases, their ideas for solving the problem.

In the event, 21 completed operator questionnaires were received. Table 2 provides a brief summary of the numbers & types of firm who responded.

Table 2. Operator questionnaires - numbers and types of firm surveyed

Type of firm or commodity	Number	Comment
Foodstuffs	4	Includes firms carrying other categories of goods as well as foodstuffs
Construction & waste	8	Includes firms carrying other categories of goods as well as construction & waste
Chemicals	2	-
General haulage	2	Includes firms carrying at least three different categories of goods
Other types of goods	1	-
Bus/coach operators	4	-
Total	21	-

TRL also aimed to generate 30 completed questionnaires from heavy vehicle manufacturers and component suppliers. A number of firms again offered to take part in the survey. However, these tended to be those involved in the design and/or manufacture of components for solving wheel fixing problems (i.e. locking devices or indicators). The other firms who completed questionnaires were (with two exceptions) manufacturers of vehicle *components* (e.g. axles or bodies) or vehicle *trailers*.

In the event, only 12 completed manufacturer/component supplier questionnaires were returned despite repeated attempts to involve a number of heavy vehicle manufacturers, including firms with ongoing links with TRL. Table 3 provides a summary of the numbers & types of firm who responded.

Table 3. Manufacturer questionnaires - numbers and types of firm surveyed

Vehicle or component manufactured	Number of firms	Comment
Wheel fixing components	6	Includes one firm involved in the design (but not manufacture) of such components
Trailers	2	-
Body manufacturer	1	-
Axles	1	-
Heavy goods vehicles	1	-
Other	1	Marketing company for bus/coach manufacturer
Total	12	-

The results of these three surveys are summarised in section 3.

2.5 Review of wheel fixing standards and tightening methods

A literature review was carried out to identify what standards existed regarding the design and construction of wheel fixings and to consider what nut tightening procedures were used within the heavy vehicle industry and in other applications requiring high loads and reliability. The results of this review are summarised in section 3.5.

3 Summary Results

3.1 Overall frequency of wheel fixing problems in the UK

The research has produced a wide variety of estimates of the frequency of wheel fixing problems in the UK. Table 4, below, summarises these estimates to allow a comparison and an analysis of the relative strengths and weaknesses of the data sources.

Table 4. Summary of estimates of the frequency of wheel fixing problems in the UK.

Information source	Predicted number of incidences per year					
	Wheel nuts loose or missing	**Other fixing defects (e.g. stud failures)**	**Wheel detachment**	**Damage only collision as a result of detachment**	**Injury accidents as a result of wheel detachment**	**Fatal accidents as a result of wheel detachment**
VOSA Survey(DETR, 1998)	7,990		175			
ACPO Survey (DETR 1998)			368	140	16	0
VOSA Survey (TRL 2005)	3,886		254			
TRL driver survey (2005)	206,047		4,547			
TRL operator survey (2005)	1,206		132			
VOSA prohibition database (2002-2005)	8,520	2,031	224			
VOSA Collision database				80% of all accidents involving wheel detachment	16% of all accidents involving wheel detachment	4% of all accidents involving wheel detachment
HVCIS fatal database (1988-2001)						4

Shaded cells are those in which the information was not available from the relevant study

It can be seen that the estimates vary quite widely but, with the exception of the TRL driver survey, there is general agreement that the frequency of loose or missing wheel nuts is in the low thousands each year, the frequency of wheel detachment is in the low hundreds each year and that fatalities resulting from wheel detachment are likely to be in single figures.

When considering the variation, particularly for the driver survey, it is important to consider the sample sizes, strengths and weaknesses of each method:

- VOSA (DETR, 1998) – VOSA would have examined about 20,000 vehicles during the period of the survey, which represents approximately 4% of the UK heavy vehicle fleet at that time. However, these will have been inspected at roadside inspections, operators' premises and after accidents. For loose or missing nuts, the sample may be biased toward older vehicles because of the nature of a targeted maintenance enforcement programme. It could be argued that VOSA would be likely to be called to a large proportion of incidents involving full wheel detachment so this may be less affected by the bias. The estimate produced from this survey should be reasonably accurate but may tend toward an over-estimate for loose/missing nuts because it has been shown that older vehicles are more likely to suffer such problems.
- ACPO 1997 – This was based on the Police completing a form each time they identified a wheel fixing problem. The nature of the division of work between VOSA and the Police meant that most of the forms completed were for wheel detachment incidents/accidents. The difficulty with this sample was that there was no easy measure of exposure to be used so the estimates in Table 4 were derived by simply multiplying the actual number recorded in three months by four to make an annual estimate. It could be argued that the real number of detachments would be greater because the Police may not be called to every incident. However, it could also be argued that low frequency events such as this vary considerably in frequency on a random basis such that there could be substantial inaccuracy in the annual estimate resulting in either over or under estimation.
- VOSA 2005 – This is very similar to VOSA 1997 and has the same strengths and weaknesses. The sample was larger this time because the survey lasted for three months and about 30,000 vehicles, or approximately 5.5% of the vehicle fleet, would have been examined. However, when the survey results were compared with the prohibition database, it became apparent that there seemed to be a substantial level of under-reporting to TRL of wheel nut defects. The number of annual prohibitions for wheel nut defects, divided pro-rata to gain a number for the three month duration of survey, was considerable greater than the number of reports TRL received from VOSA. However, when the numbers of wheel detachments were compared the two sources offered consistent data, suggesting that it is likely that TRL received a report for nearly all wheel detachments attended by VOSA during the period.
- TRL driver survey – 521 drivers were surveyed. The total number of regular heavy vehicle drivers in the UK is unknown but if it is assumed that there are 1.2 drivers for every heavy vehicle then there is likely to be around 640,800 drivers. This means that the survey sample was approximately 0.08% of the driver population and hence, relatively small. It is apparent that the results of the driver survey predict frequencies of wheel fixing problems that are orders of magnitude greater than any other source of data. The reason for this is not known but it may be due to the small sample size or a bias introduced by the location and circumstances in which interviews were carried out. It may also be that drivers were estimating the frequencies based on how often they were aware of problems occurring amongst colleagues, acquaintances and other companies, rather than just relating how often it had happened to them personally.
- TRL operator survey – twenty one operators responded to the survey but between them they represented organisations that operated 27,565 vehicles, which represents approximately 5% of the current UK fleet. This can, therefore, be considered a reasonably large sample. The sample was varied to get both large and small operators but it is not known how well this mix represents the mix of operator size nationally. It is, therefore, possible that there is some bias toward large or small operators, most likely toward large operators. In a blame culture, where

legal liability is likely to rest with the operator in the event of a wheel detachment, there may also be a perceived incentive for operators to under-report problems.

- VOSA prohibition data. This is a rigorous database formed from the ongoing enforcement activities of VOSA and a record will be entered every time a prohibition is issued. The sample of vehicles examined is approximately 120,000 per year, which represents approximately 22% of the vehicle fleet. This is, therefore a very large sample.
- VOSA collision data – The collision database is substantially skewed in relation to the national database of accidents, STATS 19. This is because its contents are entirely dependant on what accidents that the Police ask VOSA to get involved in. In general, it is nearly all related to heavy vehicle accidents and it is very strongly biased toward fatal and serious accidents but can also include damage only accidents (which are not recorded on STATS 19). Because of the nature of incidents that the Police are likely to call VOSA to, it can be assumed that wheel loss incidents are more representative, being an area the police are likely to want more mechanical expertise. This can be seen in the fact that the distribution of injury severity in wheel detachment accidents is completely different to that for other accident types. The data can be used to compare the types and severity of wheel loss accident that occurs but the frequency cannot be reliably multiplied up to national level.
- HVCIS fatal data – The HVCIS fatal database involves detailed study of police fatal accident reports. The data studied in this report represented 40% of all heavy vehicle fatal accidents recorded on STATS 19 for the time period. It is, therefore, a very large sample and it has been shown to be representative of the national situation. This is likely to be a very reliable source of data but can only provide information on the number of fatal accidents, not on the frequency of wheel fixing problems more generally.

In order to provide a useful cost benefit analysis (reported in the Regulatory Impact Assessment, Bartlett *et al*, 2006), TRL had to predict where, within the very wide range of results, it was most likely that the true answer lay. It was not possible to do this in a rigorously scientific manner so a range of assumptions were required, as described below:

- The subjective opinions of the drivers surveyed substantially over-estimated the frequency of occurrence and should be ignored.
- The frequency of occurrence reported by heavy vehicle operators under-estimated the scale of the problems and should be ignored.
- The VOSA prohibition database and the HVCIS fatal database were the most robust and representative sources of information and should be considered.
- The wheel fixing defects recorded in the prohibition database as “other” could also lead to wheel detachment and should be considered. These include fractured wheels, loose hub mounting bolts etc.
- The ACPO survey in 1997 accurately identified the proportion of wheel detachment incidents that resulted in a collision with another vehicle/road user (42%). This proportion should be used to estimate the number of all accidents based on the estimates of wheel detachment frequency from VOSA surveys and prohibitions data.
- The VOSA collision database accurately reflected the distribution of accident severity (4% fatal, 16% injury, 80% damage only) where wheel detachment was involved but not the absolute frequency of occurrence. This should be used to estimate how many of the predicted total number of accidents were damage only, injury or fatal. The HVCIS fatal estimate was used as a “sanity check” for this method of estimating accidents.

Based on a combination of the strengths and weaknesses of the data sources and the assumptions listed above, TRL has produced a broad range of estimates of the average number of each wheel fixing problem that typically occurs each year. These are shown in Table 5, below.

Table 5. TRL estimate of frequency of wheel fixing/detachment problems

	Estimated number of incidents per year				
	Wheel fixing defects (i.e. loose, missing, damaged nuts, damaged, failed studs)	Wheel detachment (All)	Wheel detachment (damage only accident)	Wheel detachment (injury accident)	Wheel detachment (fatal accident)
Upper estimate	11,000	400	134	27	7
Lower estimate	7,500	150	50	10	3

3.2 Trends over time

It was not possible to identify any definite trends over time because the various sources of information provided conflicting information, as summarised below:

- The VOSA surveys (1997 & 2005) suggested that the frequency of loose or missing wheel nuts had decreased by 51% at the same time as the number of detachments had increased by 45%.
- The ACPO surveys (1997 and 2005) suggested a massive decrease in wheel detachment but it was clear that this was due to a lower participation of the police in the second survey (for a variety of reasons).
- The results from the VOSA collisions database suggested that the frequency of heavy vehicle wheel detachment accidents had decreased since 1997. However, the collection and reporting methods had changed substantially in the intervening period and there was no measure of exposure available to try to quantify this further so it was not possible to be confident with the suggestion.
- The VOSA prohibitions database suggested that the total number of all HGV prohibitions for wheel defects had remained almost constant over the three years for which data was available.
- The HVCIS database showed a very slight suggestion that the rate of fatal wheel detachment accidents had decreased over time since 1988 but the correlation was very weak and not statistically significant.

The conflicting evidence means that it is only possible to state that wheel detachment problems do still occur and that any change in the frequency of occurrence has not been sufficiently large to be reliably detectable given the limited monitoring and reporting methods available.

In future, it is likely that trends could be monitored using the VOSA prohibition database in combination with accurate exposure data concerning the number of vehicles examined. However, it may take some years after the implementation of a mitigation measure for any trend to become noticeable because problems become more frequent on older vehicles and VOSA's enforcement activity tends to be biased toward older vehicles that are more likely to have problems.

3.3 Frequency of occurrence by location of defect

In previous literature, there has been much discussion of bias toward problems occurring on the nearside (left) of the vehicle. Table 6, below, presents a summary of all of the information studied.

Table 6. Proportion of defects occurring on each side of the vehicle

Study	Loose or missing nuts		Wheel detachment	
	Nearside (left) %	Offside (right) %	Nearside (left) %	Offside (right) %
VOSA survey (DETR, 1998)	54	46	-	-
VOSA survey 2005	60	40	71	29
ACPO survey (DETR, 1998)	-	-	79	21
ACPO survey 2005	-	-	78	22
VOSA collision database	-	-	88	12
VOSA Prohibition database	54	46	80	20
Mean	56	44	79	21

Note: percentages exclude location unknown. ACPO (DETR, 1998) figures did not separate detachment and loose/missing in analyses of location but 74% of all cases were detachment

It can be seen that for all defects there is a bias toward problems occurring on the nearside. However, the bias is relatively small simply for loose or missing wheel nuts (56/44) but is very large for wheel detachments (79/21). This suggests that the side of the vehicle has a minor influence on the cause of the wheel nut working loose in the first place but may have a much greater effect on the time taken for loose nuts to work all of the way off of the thread to permit a wheel detachment.

The perception of drivers was close to the objectively observed rates above for loose wheels with 57% reporting that problems were more likely on the nearside. However, operators (69% nearside) and manufacturers (80% nearside) perceptions appear to be more related to wheel detachment.

VOSA's survey showed a strong bias towards problems occurring on drive axles (46%) compared with steer axles (29%) and free rolling axles. The perceptions of drivers and operators (40% and 62% respectively) agreed with this objective finding. However, manufacturers disagreed with 60% reporting the steer axle to be more likely, although it should be noted that the number of respondents to this question was small (5).

3.4 International information on wheel detachment

The requests for data from other countries clearly demonstrated that loose wheel fixings and wheel detachment are recognised problems in many countries both within the EU and around the world. In total, responses were received from 14 different countries, none of which stated that there were no problems with wheel fixings, although five could not offer an opinion because of a lack of data on any problem.

A lack of data was a problem for many countries, which has made it impossible to accurately assess the relative frequency of occurrence in different countries. However, a detailed report from Finland showed that approximately 150 cases of wheel detachment per year were reported to the Police and estimated that there might be a "*few hundred*" cases in total. Canada reported 745 wheel detachments in 7 years and Japan reported 63 detachment incidents in 2004 and noted that recording of this problem was relatively new and that reporting levels were still increasing. Although the relative scale of the problem cannot be accurately quantified, it is possible to state that the levels reported are broadly comparable with those in the UK.

Detailed studies were rare so, in most cases, it was not possible to compare detailed causes. However, the Finnish study produced some very interesting results relating to which side of the vehicle detachment was more likely.

All of the UK studies showed that wheel detachment was much more likely to occur on the nearside of the vehicle. Typically, two reasons are put forward for this. One is that the direction of rotation of the wheel in relation to the thread of the nut differs from side to side such that the rotation of the wheel tends to unscrew a right handed threaded nut when it is fitted to the left side of the vehicle but would tend to tighten the same nut fitted to the right side. This has been used in the past to justify fitting left handed threads to the left side of vehicles. The other theory frequently put forward is that, in the UK, the left hand side of the vehicle is adjacent to the kerb and is exposed to poorer condition road surfaces, carries greater load due to the effect of camber and carries an increased risk of kerb strikes.

In Finland, 34 (89%) of 38 incidents of wheel detachment that were studied in detail occurred with wheels fitted to the left side of the vehicle. In Finland, the left hand side of the vehicle is on the offside and is toward the centre of the road. The theory for this put forward in Finland was that wheels becoming detached from that side of the vehicle were more likely to collide with oncoming traffic and were, therefore, more likely to be reported to the Police.

When comparing the findings of UK and Finnish studies, it is apparent that the Finnish theory on the reasons for the bias to the left would not hold true in the UK. It is also apparent that the UK theory about the left wheel carrying more load would not hold true in Finland. A comparison of the two sets of data lends support to the theory developed from the UK data that although the side of the vehicle (i.e. direction of rotation and handed threads) has only a small effect on nut loosening it may have a much greater effect on the rate at which a loose nut becomes a wheel detachment. It should be noted that if this theory is correct then fitting handed threads would only be expected to reduce the severity of the consequences of wheel nut loosening (in terms of how quickly a loose nut became a wheel detachment and hence how likely the defect is to be rectified before wheel detachment) but would not be expected to be particularly effective at solving the root problem of nut loosening.

In addition to this, studies in Finland, Canada, and Japan also noted statistical frequency effects related to temperature, with a greater frequency occurring in winter. In Finland, this was to the extent that 66% of all detachments occurred in winter, 71% at temperatures of below zero degrees Celsius. In the UK, the VOSA prohibition data showed a very slight (2%) bias toward the winter months but it may be that this slight effect, in comparison to Finland, is because the winters are less severe in the UK.

3.5 Wheel fixing standards and tightening methods

It was clear that there has been extensive research into the design of wheel fixings and the tightening methods used with relation to the problems of loose fixings and wheel detachment and the mechanisms through which it occurs now seem well understood. The literature reviewed suggested that the current designs of wheel fixings do provide adequate clamp load when all components are in good condition and properly tightened. However, it also shows that there can be substantial problems involving joint relaxation, torque to clamp ratio and temperature effects that can affect the security of the fastening. The data suggests that the factor of safety inherent in the current designs is not so high that it can tolerate large amounts of degradation of components or imperfect maintenance procedures. The current design is NOT a maintenance free design and does, therefore, require very careful handling.

Maintenance issues have also been subject to considerable research and an extensive range of comprehensive procedures has been published by a variety of organisations recommending good practice in terms of how to re-fit a wheel and tighten the nuts. Most of these procedures are in agreement over the main principles but there are still some conflicting recommendations and some that are made by only a small number of organisations as described below:

- Issues typical to all procedures
    - Daily checks of nut security should be carried out
    - Periodic checks/re-torques should be carried out (e.g. every 6 months)
    - Torque should be set with a calibrated torque wrench and power tools/long extension bars should not be used for final tightening. Two procedures did permit the use of a socket and bar of specified length.
    - Mating surfaces should be free from rust and dirt etc and any paint should be microscopically thin
    - Nuts should be tightened in a criss-cross sequence.
    - Parts should be correctly matched i.e. flat nuts and wheels with plain holes for spigot located wheels
    - Take care not to damage studs when fitting wheels and ensure the nuts run freely down the whole length of the stud by hand
    - Use trained personnel
    - Keep records of wheel maintenance for specific vehicles
    - If loose nuts are found the problem should be investigated – nuts should not simply be re-tightened
- Issues where requirements vary
    - Tightening torque: Most of the procedures reviewed specify following manufacturers' requirements. However, one general guideline recommended specific values based on stud size alone and two suggested the manufacturer's requirement or a specific value. Specific quoted values (including manufacturers' requirements) varied widely from 500Nm to 850Nm.
    - Lubrication of stud/nut threads and interfaces. Most general guidance recommends lubrication, two general guidelines permitted it but did not recommend and one specifically prohibited it, although this related only to stud-piloted wheels. However, some manufacturers' recommendations specifically recommend not lubricating for specific vehicle types.
    - Re-torquing. All guidance recommended re-torquing after a wheel was re-fitted. However, some recommended re-torquing after a specific distance, which varied from 40km to 200km, and some recommended re-torquing after 30 minutes with the vehicle stationary and some permitted either method.
    - Re-torquing: Some procedures stated that when re-torquing that the nuts must not be slackened and then re-tightened, others specifically stated that if a loose nut was found all nuts must be fully slackened and re-tightened.
- Specific recommendations made in a minority of the guidelines and not prohibited by the majority
    - Tighten nuts to a "snug" torque and then use a pre-determined angle of nut rotation for final tightening
    - Examine wheels, studs and nuts for damage, cracking and distortion and renew if necessary
    - Check that studs and nuts conform with BS AU 50
    - Ensure that the wheel is correctly positioned with respect to the hub
    - Lubricate the hub spigots and wheel bore

- Ensure the spigot is in contact with the wheel for at least 3 mm
- Ensure that the wheel brake is not applied during wheel fitting

Current best practice would clearly constitute implementing all of the items in the first group. With respect to those where there is some doubt, most guidelines recommend lubricating the threads and following manufacturers' guidelines with respect to torque or using a default value specified by another standard where the manufacturer's value is unknown seems the safest option. However, this situation is less than ideal and does allow the potential for human error. If all studs and nuts comply with BS AU 50 and vehicles of similar sizes all had the same number/size of stud then there seems no obvious reason why standard torque values could not be applied to all vehicles based on stud size alone, thus reducing the potential for error. It is not known which option would be safer in relation to the third item in that group about methods of re-torquing.

For the third group, which represents requirements specified in only a minority of cases, best practice is not clear. Angle tightening certainly offers the potential to reduce the initial variation in clamp load that occurs as a result of variable friction between the threads and between the nut and wheel face. However, this can only be implemented where the manufacturer has issued a guideline and it is not known how easy wheel fitters would find it to adhere to accurately in practice. Checking for damage and renewing parts seems to be common sense as does checking that components comply with standards. However, no information was found that described the effect that lubrication of spigots, ensuring spigots are in contact for at least 3mm, or ensuring that the brake is not applied would have.

The importance of understanding of best practice in relation to maintaining wheel fixings was illustrated by the survey responses. Although nearly all operators reported that they had procedures in place to deal with wheel maintenance, the survey responses identified some alarming deviations from best practice:

- 100% of operators reported that their drivers should carry out daily visual checks and 95% reported that this should include a specific check of wheel nut security. However, only 76% of drivers reported always carrying out daily checks, only 68% specifically looked for wheel fixing defects and 2% reported never carrying out daily checks.
- One third of drivers did not know how frequently wheel nut security was checked as part of the scheduled maintenance of their vehicle.
- 5% of operators reported never checking wheel security during routine maintenance
- 50% of drivers reported using re-torque procedures after a wheel was refitted that were not in accordance with the best practice guidelines. Forty two percent of operators also reported re-torque procedures that differed from best practice. Twenty four percent of operators wait until the next safety inspection before re-torquing and 5% reported never re-torquing the fixings after a wheel change.

In addition to the above, the survey did show some correlation between the use of correct maintenance procedures and their self reported level of wheel fixing problems. For example, a much higher proportion of those drivers who had never experienced wheel fixing problems carried out daily inspections compared with those drivers who had experienced problems. It is clear that, given the current design of wheel fixings, maintenance has a critical role to play and it is also clear that there is substantial scope for further improvements in maintenance. While an improved standard of maintenance clearly has the scope to reduce the frequency of wheel fixing problems, it seems unlikely that improved maintenance alone will eliminate the problem entirely. This is also supported by the results of the survey where it could be seen that even those operators and drivers who did report using procedures in accordance with best practice still reported experiencing some wheel fixing problems.

3.6 Potential solutions

A range of possible solutions or improvements to the problems were identified:

- Measures that may have the potential to prevent the problem occurring
    - Fundamental change to wheel fixing design
    - Wheel nut retention devices (based on manufacturers' literature – no independent assessment carried out)
        - Disc-lock
        - Wheelsure
        - Wheel crown
- Measures that may have the potential to mitigate the consequences of loose nuts
    - Directionally threaded wheel nuts
    - Nut movement indicators
        - Ric-clip
        - Wheel-ex
        - Safety trim
        - Check-link

Physical assessment of the effectiveness of these measures was beyond the scope of this project and may be considered for further study in the future. However, the views of drivers, operators and manufacturers in relation to a selection of the measures were obtained.

With respect to the fundamental design of wheel fixings, it was apparent that other industries such as the airline industry used completely different wheel fixing methods that would not be expected to have the same fixing problems. However, 75% of manufacturers did not believe that the current design was inadequate. Only 38% of operators had the same belief but 43% of the operators were not sure, such that only 19% positively identified the current design as inadequate.

With respect to the add-on solutions such as nut retention or movement indicator devices, the views were generally very positive, particularly from drivers. However, in face to face consultation with members of the industry, concern was expressed about the possibility of operators becoming complacent and relying on the devices, to the detriment of basic maintenance. Most of the small group of operators spoken to and most manufacturers of the add-on devices themselves agreed that such solutions could form a valuable supplement to rigorous maintenance procedures but could not replace them.

This view is supported by the fact that during VOSA's survey, 2% of the wheel defects that were recorded involved wheels that were equipped with a nut retention device and 15% occurred on wheels equipped with nut movement indicators. This shows that fitting such measures alone will not eliminate problems. However, if more than 2% and 15% respectively of vehicles in the fleet are fitted with such devices then there would be evidence to suggest that they did reduce the problem. Unfortunately it was not possible to accurately quantify how many vehicles were fitted with devices. It is recommended that further work be carried out to more objectively assess the effectiveness of such solutions and, if shown to be effective, to develop minimum technical standards for the devices and standard guidance for the maintenance of them.

4 Analysis

TRL has estimated, based on the data developed during this project and a range of assumptions, estimates of the annual frequency of a range of wheel fixing problems. These are shown in Table 7, below.

Table 7. TRL estimate of frequency of wheel fixing/detachment problems

Estimate boundary	Estimated number of incidents per year				
	Wheel fixing defects (i.e. loose, missing, damaged nuts, damaged, failed studs)	**Wheel detachment (no collision)**	**Wheel detachment (damage only accident)**	**Wheel detachment (injury accident)**	**Wheel detachment (fatal accident)**
Upper estimate	11,000	400	134	27	7
Lower estimate	7,500	150	50	10	3

The theory of bolted joints offers no obvious reason why wheel nut loosening should be more prevalent on one side of the vehicle or on a particular axle. In particular, the relative size of forces involved suggests that it is extremely unlikely that the direction of wheel motion in relation to the thread direction would be of influence. However, the statistical evidence shows that there is a bias of approximately 5% towards nut loosening occurring on the nearside (left) and a relatively strong bias toward problems occurring on the drive axle. The basic bolt theory would suggest that this must be because the wheels on the nearside and the drive axle are exposed to higher operating forces due to poorer road surfaces, camber leading to higher vertical load, increased risk of kerbing, and exposure to drive torque in addition to braking and cornering etc.

The statistical data also shows that the bias toward the left is considerably greater for full wheel detachments than it is for loose or missing wheel nuts. In addition to this, a study in Finland showed that there was a strong bias in wheel detachments occurring on the left despite the fact that they drive on the right and the left is, therefore, the offside of their vehicles and, therefore, travels in the centre of the road. It is possible that the reason for this is the rotational forces applied to the nut, which could act to unscrew a nut with a right handed thread when it is fitted to the left of the vehicle, thus meaning that a loose nut on the left wheel becomes fully detached much more quickly than a loose nut on the right. It is, therefore, possible that directionally threaded nuts could reduce the consequences of nut loosening by slowing the process between nut loosening and full wheel detachment by permitting increased time for the defect to be identified and rectified.

Bolt theory also suggests that temperature variation can have an effect where wheels, studs and nuts expand with increasing temperature at different rates, leading to a reduction in clamp force. This is supported by statistical studies showing increased incidence of wheel fixing problems in cold weather where a greater change in temperature will occur due to braking during the journey.

The research has shown that the fundamental design of wheel fixings is adequate to retain the wheel when the components are all in good condition and the torque is correctly set. However, a torque of between 500Nm and 850Nm (depending on manufacturer's recommendation) is required to generate sufficient clamp force to adequately restrain the wheel and this must be maintained despite the substantial variation that can occur due to:

- Joint settling immediately after first tightening
- Variation in the torque to clamp force ratio due to changes in friction between the threads and mating surfaces

- Temperature effects

All of this must be achieved without exceeding a clamp load equivalent to a torque of in the region of 1,200Nm where yielding of the studs can occur. These fundamental constraints mean that very careful maintenance of the joint is required, particularly as components get older. A wide range of guidance on how best to achieve this maintenance is now available and does agree on most main points. However, there are still some areas such as the actual torque setting itself and lubrication of studs and nuts where recommendations can vary considerably from manufacturer to manufacturer, leading to an increased potential for human error. It may well be beneficial to standardise further the recommended wheel fixing advice.

The survey of operators showed that most reported having formal maintenance procedures in place to cover wheel detachment. However, more detailed questions revealed that a relatively large proportion did not follow the best practice guidance discussed above and some admitted to fundamental differences such as never re-torquing a wheel shortly after it was re-fitted. In addition to this, it could be seen that although all operators stated drivers should carry out daily inspections, quite a large proportion of drivers admitted that they did not always carry this out and some admitted that they never did. There was some evidence to suggest that those drivers and operators that did adhere more closely to best practice procedures were reporting a lower incidence of wheel fixing problems.

A range of potential solutions to the problem were identified and, in general, these were viewed quite positively by the industry. However, independent assessment of their effectiveness was beyond the scope of this study and there was evidence from the VOSA survey to demonstrate that add-on solutions such as nut retention devices or movement indicators would not be 100% effective.

It is also important to place the wheel detachment problem in context with wider road and vehicle safety issues. Although the number of loose or missing wheel nuts each year (7,500 to 11,000) appears to be high the number of serious accidents is relatively low. The HVCIS accident study predicted that as an average between 1988 and 2001 there were four fatalities as a result of wheel detachment each year. If this data had been restricted to only more recent data that estimate would have dropped further. On average, the HVCIS data predicted that wheel detachment was responsible for only 0.57% of all fatalities arising from heavy vehicle accidents. By contrast, national accident statistics show that 55% of all people killed in accidents involving an HGV were in a car that collided with the HGV. Knight (2000) used HVCIS data to predict that 11% of fatally injured car occupants (6.5% of all fatalities in HGV accidents) that were in collision with an HGV could have been protected by fitting front underrun protection (note that front underrun protection was made mandatory for new trucks sold in the EU in 2003). This represents more than 11 times the number of people that could be protected by eliminating wheel detachment entirely.

Although it is clear that a problem exists with wheel nut security and that it can and does result in fatal accidents, it is also clear that in purely objective terms it is of lower priority in terms of fatality prevention. However, probably because of the perception that a wheel detachment *should* be entirely preventable because it is purely mechanical and involves no obvious error in the way the vehicle is driven, there tends to be a higher profile and significance attached to wheel detachment accidents. This is reflected in the survey results. In order to try to quantify how seriously the issue of loose wheel fixings or wheel detachment is perceived in the wider context of heavy vehicle safety, the respondents to the questionnaires were asked to rate the severity of a number of heavy vehicle safety issues. The average results for this question are shown in Figure 1.

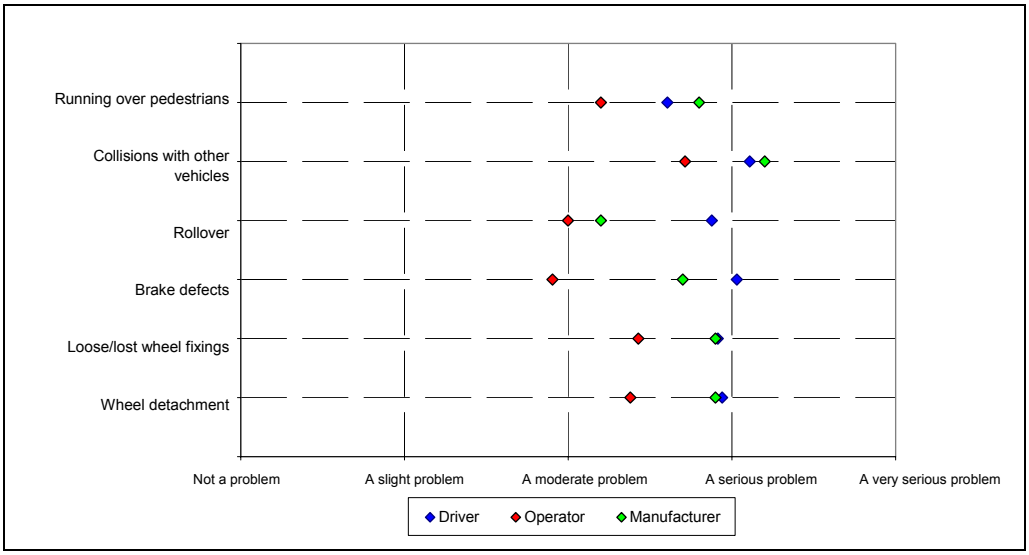

Figure 1: Heavy vehicle safety issues

On average the drivers rated the severity of the safety issues more highly than the operators or manufacturers. The issue of collisions with other vehicles was consistently rated as the most serious problem but not by as large a margin as the fatal accident statistics would suggest, where approximately three-quarters of all fatalities involved collisions between vehicles compared with 0.57% involving wheel loss. The issue of running over pedestrians was rated the least severe by the drivers despite the fact that this accident type represents approximately 17% of all fatalities in accidents involving HGVs. The issue of brake defects was rated least serious by the operators and manufacturers, which is closest to the ranking provided by fatal accidents where brake defects were a contributory cause in approximately 3% of fatal accidents involving HGVs.

The issues of loose wheel fixings and wheel detachment were rated second and third behind collisions with other vehicles, except by the drivers who also rated brake defects second.

5 Conclusions

1. The various studies carried out produce quite variable estimates of the frequency of wheel fixing problems. However, with the exception of the TRL driver survey, there is general agreement that the frequency of loose or missing wheel nuts is in the low thousands each year, the frequency of wheel detachment is in the low hundreds each year and that annual fatalities resulting from wheel detachment are likely to be in single figures.

2. Based on the data and a range of assumptions about the data, TRL has estimated that the typical annual frequency of wheel fixing problems is between 7,500 and 11,000 wheel fixing defects resulting in between 150 and 400 wheel detachments. Of the wheel detachments, it was estimated that between 50 and 134 would result in damage only accidents, 10 to 27 in injury accidents and 3 to 7 in fatal accidents.

3. It was not possible to reliably determine whether the frequency of occurrence has changed since 1997 and the publication of "Careless Torque". There was some evidence to suggest that the frequency had decreased but there was also some conflicting evidence that it had stayed constant or increased.

4. Requests for data on wheel fixing problems were sent to a wide variety of countries. There is sufficient evidence of wheel fixing problems to state confidently that this problem is not unique to the UK. There was insufficient detailed information to enable an accurate comparison with the estimated frequency of occurrence in the UK but there was sufficient evidence to suggest that the levels are "broadly comparable".

5. There is a bias toward problems occurring on the nearside of vehicles (i.e. left in the UK). However, this bias is small for loose wheel nuts but large for wheel detachments suggesting it may be of small influence in the root cause of nut loosening but may have a larger influence in the rate of progress between the first nut loosening and full wheel detachment.

6. Findings in Finland showed that there is a strong bias toward wheels becoming detached from the left side of vehicles, the same as in the UK, despite the fact that they travel on the opposite side of the road. This lends support to the theory that the direction of wheel rotation in relation to thread direction could have an influence on how quickly a loose wheel nut turns into a full wheel detachment.

7. Findings in Canada, Japan and Finland all suggest that colder temperatures can increase the frequency of wheel detachment.

8. There has been a considerable amount of research into the mechanics of wheel nut loosening and the causes are now well understood. Clamp load is considered the main parameter and the clamp load must be sufficiently high to withstand all applied forces despite any effects of joint relaxation, variation in the torque to clamp ratio, relaxation due to temperature. However, this must be achieved without the clamp force being so high that the yield point of the stud is exceeded.

9. Current designs of wheel fixing are capable of achieving this providing joint relaxation is accounted for with re-torquing and all components are in very good condition. However, the factor of safety allowed means that considerable maintenance of the joint is required to maintain its effectiveness over several years' service, particularly where vehicles are exposed to harsh operating environments.

10. A wide range of best practice guidelines are available that recommend practice and procedures for fitting and maintaining wheels. In general, the research into wheel fixing problems has meant that many of the requirements are now common to all of them but there are still areas such as actual torque levels and the issue of lubrication where there is not a standard approach. Further development towards common standards may well be beneficial.

11. Although most operators (86%) reported that they do have formal policies and procedures in place regarding wheel fixings, the survey showed evidence to suggest that these were quite

often not in accordance with the guidelines discussed above. For example, 12% of operators reported "never" re-torquing a wheel after it has been refitted.

12. Similarly, there was strong evidence that a large proportion of drivers did not understand and/or adhere to the best practice requirements. For example, despite all operators stating that drivers should conduct a daily visual inspection, 26% of drivers admitted not always doing this and 32% admitted not always looking for signs of loose wheel nuts. Two percent admitted to "never" carrying out daily visual checks.

13. The surveys also showed that there was evidence to suggest that those drivers or operators who better understood and adhered to the requirements reported a lower incidence of wheel fixing problems.

14. It can, therefore, be seen that maintenance is a key issue for the current design of wheel fixing. The theory shows why it is important in physical terms, there are a range of guidelines in existence, there is evidence to show that these guidelines are not always followed and some evidence to show those that do follow them report lower levels of wheel fixing problems.

15. A range of potential measures capable of reducing the frequency of occurrence or mitigating the consequences were identified. These range from indicators of wheel nut movement to a complete redesign of wheel fixing methods. The physical effectiveness of these potential solutions was not evaluated but the survey showed that they were generally perceived to be beneficial by the industry. However, 2% of the defects found in the VOSA survey were found on vehicles equipped with wheel nut retention devices and 15% were found on wheels fitted with movement indicators. This shows that adding these devices alone will not eliminate the problem, although it may well reduce it, and good maintenance practice will still be required.

16. A substantial difference was found between the perceived importance of wheel fixing problems in relation to other heavy vehicle safety issues and the relative importance as shown by fatal accident statistics. The industry respondents considered wheel fixing problems as second only to collisions with other vehicles. However, fatal accident statistics showed that wheel detachment contributed to 0.57% of fatal accidents whereas about three-quarters of fatalities in accidents involving HGVs involved collisions between vehicles, 17% involved collisions with pedestrians and approximately 3% involved contributory brake defects.

6 Recommendations

1. It is recommended that a method for routinely monitoring the frequency of wheel fixing problems is developed. The most appropriate data source currently available would be the VOSA prohibition database combined with detailed exposure data describing the type and number of vehicles examined each year. Such a data source would be expected to miss a number of incidences that go un-reported. More comprehensive data could be obtained but this would require the development of a new or modified source of data.

2. It is recommended that consideration is given to implementing measures to reduce the incidence of wheel nut loosening and wheel detachment. The measures to be considered should include:

    a. Further standardisation of best practice wheel tightening procedures, in particular, simplifying the identification of recommended torque settings and standardising on the use of lubrication.

    b. Further education and or enforcement to encourage universal adoption of rigorous wheel maintenance procedures.

    c. The possibility of a fundamental re-design of the method of wheel attachment for heavy vehicles to produce a much lower maintenance solution.

d. The potential mandatory use of wheel nut retention devices, if independently shown to be effective.

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