Svenska däcksäkerhetsrådet

Wheel loss on Swedish Roads

The Swedish Tire Safety Council – Svenska däcksäkerhetsrådet

Working Group “Age of tires/tire failures” – Arbetsgrupp “Ålder på däck/däckhaverier”

March 2024

1. Contents

2. Summary

Background and Method:

- The Swedish Tire Safety Council ("Svenska Däcksäkerhetsrådet") is a forum for exchange of knowledge, experience, and expertise of tires with particular focus on the Swedish Vision Zero goal of no fatalities or severe injuries in Swedish road traffic. The council identified wheel loss in Sweden as in issue to investigate. Input came from studies conducted in other markets, showing that wheel loss may be a risk factor to be considered.
- This study and report have been conducted, analyzed and written by the working group Age of tires/Tire failures ("Ålder på däck/däckhaverier") within The Swedish Tire Safety Council.
- Most of the data, analysis and the present report are based on the results from an online consumer survey with app. 5,000 respondents, conducted during the spring of 2023.
- A previously unpublished small study conducted by VTI on accidents leading to personal injury in connection with lost passenger car wheels is included in as an appendix.

Results:

- 6 percent of the respondents have been in a car that has lost a wheel within the last ten years.
- If the result of the study is representative for the whole population of passenger cars in Sweden, about 30.000 passenger cars lose a wheel annually in Sweden.
- According to the study results, 3 percent of the incidents with wheel loss among passenger cars cause a traffic accident.
- If the result of the study is representative, an estimated 900 traffic accidents are caused by wheel loss on passenger cars annually.
- VTI's investigation of accidents leading to personal injury reported in the Swedish accident database Strada suggests 3 accidents per year that leads to personal injury connected with a passenger car wheel loss. However, there is reason to believe that the actual numbers may be higher than this, since the search was rather limited, and because not all accidents are reported to Strada.

Conclusions:

- The present study indicates that wheel loss is a significant technical risk factor for traffic accidents on Swedish roads.
- Wheel loss on passenger cars is considered to be the result of improper wheel change procedures and lack of awareness or knowledge by vehicle owners or workshop professionals. This is provided that the lost wheel is not caused by another serious accident or by sabotage.
- Whereas tire-related technical risk factors like tread depth, low inflation pressure or seasonally inappropriate tires have been well investigated and frequently addressed to different target groups, the topic of wheel loss has hardly been present in the media, education, or the drivers' minds.

Recommendations:

- Proper routines should always be followed when changing wheels, including:
  - Cleaning of the contact surfaces
  - Re-tighten after 50–100 km to the recommended torque.
- Both drivers and workshop staff should be frequently informed about and reminded of these routines and how important they are for traffic safety.

- Electronic monitoring systems detecting loose wheels before they completely detach should be offered, as original or optional equipment on passenger cars.
- Wheel loss and the causal contribution to accidents should be properly covered in the accident analysis and statistics, not only in Sweden, but at least EU-wide. This would enable a more detailed analysis including cost-benefit and targeted recommendations for preventive measures.

Recommendations on how to carry out a wheel change on a passenger car:

- Remove the bolts/nuts and the old wheel.
- For both the old and the new wheel, as well as the vehicle: Clean and inspect all contact surfaces, threads (and if applicable: adapters) for wear, damage, and excessive corrosion.
- Replace damaged, worn and excessively corroded parts.
- Do not lubricate the threads or surfaces before assembly. (The reason is that on passenger cars, there is then a great risk that the bolt/nut will be pulled past the yield point of the material, which leads to damage to the threads leading to a poorly fitting bolt/nut.)
- Ensure that the bolts/nuts match the rim (cone/rounded/flat).
- Mount the new wheel and tighten the bolts/nuts in a crosswise pattern to a moderate torque, well below the recommended torque and check that the wheel sits tight and flat on the hub.
- Using a correctly adjusted torque wrench, tighten the bolts/nuts in a crosswise pattern to the torque as recommended by the vehicle manufacturer.
- Note! After 50–100 kilometers of driving, re-tighten the bolts/nuts according to the previous step.

Source: The Scandinavian Tire & Rim Organization – STRO

3. Sammanfattning på svenska (Summary in Swedish)

Bakgrund och metod:

- Svenska Däcksäkerhetsrådet är ett forum för utbyte av kunskap, erfarenhet och expertis om däck med särskilt fokus på den svenska nollvisionen om inga omkomna eller allvarligt skadade i svensk vägtrafik. Mot bakgrund av undersökningar som genomförts i andra länder har Däcksäkerhetsrådet pekat ut tappade hjul för personbilar i Sverige som ett tänkbart trafiksäkerhetsproblem, och beslutat sig för att utreda detta närmare.
- Denna studie och rapport har genomförts, analyserats och skrivits av arbetsgruppen Ålder på däck/däckhaverier inom Svenska Däcksäkerhetsrådet.
- Merparten av data, analys och föreliggande rapport bygger på resultaten från en webbenkät med cirka 5 000 respondenter som genomfördes under våren 2023.
- En tidigare opublicerad mindre studie utförd av VTI angående personskador i trafik från olyckor med tappade personbilshjul är inkluderad som en bilaga.

Resultat:

- 6 procent av respondenterna har befunnit sig i en bil som har tappat ett hjul under de senaste tio åren.
- Om den andelen är representativ för hela riket så inträffar cirka 30 000 incidenter med tappade personbilshjul varje år i Sverige.
- Enligt enkätstudien så resulterar 3 procent av incidenterna i en trafikolycka.
- Om resultatet är representativt för hela riket innebär det att cirka 900 trafikolyckor inträffar årligen i Sverige på grund av tappade personbilshjul.
- VTI:s studie av olyckor med personskada i olycksdatabasen Strada indikerar att cirka 3 personskadeolyckor kan kopplade till tappade personbilshjul per år i Sverige. Denna siffra bedöms vara i underkant på grund av en underrapportering av olyckor till Strada.

Slutsatser:

- Undersökningen pekar på att tappade personbilshjul är en betydande riskfaktor för trafikolyckor på svenska vägar.
- Tappade hjul på personbilar bedöms vara ett resultat av felaktiga hjulbytesprocedurer och bristande medvetenhet eller kunskap hos fordonsägare eller verkstadspersonal. Detta förutsatt att det tappade hjulet inte orsakats av en annan allvarlig olycka eller av sabotage.
- Medan däckrelaterade tekniska riskfaktorer såsom mönsterdjup, lågt lufttryck eller säsongsmässigt olämpliga däck har undersökts väl och ofta adresserats till olika målgrupper, har tappade hjul knappt uppmärksammats alls i media, utbildningar eller hos förare.

Rekommendationer:

- Rätt rutiner ska alltid följas vid hjulbyte, inklusive:
  - Rengöring av kontaktytor.
  - Efterkontroll efter 50–100 km, till rekommenderat vridmoment.
- Både förare och verkstadspersonal bör regelbundet informeras och påminnas om korrekta rutiner för däckbyte och hur viktigt detta är för trafiksäkerheten.
- Elektroniska övervakningssystem som upptäcker lösa hjul innan de lossnar helt bör erbjudas, som original- eller tillvalsutrustning på personbilar.
- Hjulrelaterade orsaker till olyckor bör tas upp ordentligt i olycksanalysen och statistiken, inte bara i Sverige utan även i åtminstone resten av EU. Detta skulle möjliggöra en mer detaljerad analys som omfattar kostnads-nyttoanalyser och riktade rekommendationer om förebyggande åtgärder.

Rekommendationer för byte av hjul på personbil:

- Ta bort bultarna/muttrarna och avlägsna det gamla hjulet.
- För både det gamla och det nya hjulet samt fordonet: Rengör och inspektera alla kontaktytor, gängor (och i förekommande fall: adaptrar) med avseende på slitage, skador och överdriven korrosion.
- Byt ut skadade, slitna och kraftigt korroderade delar.
- Smörj inte gängorna eller ytorna före montering. (Anledningen är att det på personbilar då finns en stor risk att bulten/muttern dras förbi materialets sträckgräns, vilket leder till skador på gängorna och en sämre åtsittande bult/mutter som följd.)
- Se till att bultarna/muttrarna passar fälgen (konisk/rundad/platt).
- Montera det nya hjulet och dra åt bultarna/muttrarna i ett tvärgående mönster (korsvis) till ett måttligt vridmoment, långt under det rekommenderade vridmomentet och kontrollera att hjulet sitter tätt och plant på navet.
- Använd en korrekt justerad momentnyckel och dra åt bultarna/muttrarna i ett tvärgående mönster (korsvis) till det vridmoment som rekommenderas av fordonstillverkaren.
- OBS! Efter 50–100 kilometers körning är det dags att kontrollera att bultarna/muttrarna sitter korrekt, enligt det föregående steget.

Källa: The Scandinavian Tire & Rim Organization – STRO

4. Introduction

This study and report have been planned, conducted and written by the members of the working group Age of tires/Tire failures ("Ålder på däck/däckhaverier") within the The Swedish Tire Safety Council ("Svenska Däcksäkerhetsrådet"):

- Cecilia Blom Hesselgren, Bilprovningen – chair of the working group
- Per-Anders Blommefors, Bilprovningen
- Dennis Alexis, STRO – Scandinavian Tire and Rim Organization
- Peter Norlin, DFTF – Däck-, Fälg- och Tillbehörleverantörernas Förening
- Jörg Sturmhoebel, NIRA Dynamics AB
- Pontus Grönvall, Däckbranschens informationsråd/Däckbranschen Sverige
- Mattias Hjort, VTI – Statens väg- och transportforskningsinstitut
- Anders Ydenius, Folksam.

5. Background

5.1. The Swedish Tire Safety Council – Svenska däcksäkerhetsrådet

The Swedish Tire Safety Council is since the council's foundation in 2019 a forum for exchange of knowledge, experience and expertise of tires with particular focus on the Swedish Vision Zero goal of no fatalities or severely injured in Swedish road traffic. The council also addresses other questions related to tires and sustainability. The council has a wide variety of members representing for example the tire and wheel industry, retailers and distributors, automotive industry, authorities, research institutions, technical services, universities, insurance companies and NGO's that participate in regular meetings. The discussions and decisions of the quarterly meetings are documented. Activities between the meetings are organized and conducted by specialized working groups (WG) which are currently the following:

- WG Technology ("Arbetsgrupp Teknik")
- WG Interface Traffic Safety/Other Sustainability Issues ("Arbetsgrupp Gränssnitt trafiksäkerhet/övrig hållbarhet")
- WG Winter tires during summer ("Arbetsgrupp Vinterdäck på sommaren")
- WG Age of tires/tire failures ("Arbetsgrupp Ålder på däck/däckhaverier")

The Council uses a common project platform for communication, documentation and dialogue between the meetings. Pontus Grönvall (pontus@dackinfo.se), The Swedish Tire Trade's Information Council / The Swedish Tire Trade ("Däckbranschens informationsråd"/"Däckbranschen Sverige"), is in charge of the co-ordination within the council and between working groups.

5.2. Anecdotal evidence that wheel loss is a safety issue

In 2017, NIRA Dynamics AB entered the market with a software-based warning system capable of detecting the characteristic vibrations caused by wheels on passenger cars starting to detach from the wheel hub contact surface. The development and implementation were based on the assumption that wheel detachment (wheel loss) is a road safety concern. This was mainly based on own observations in daily road traffic, but also numerous reports from various online sources like social media, YouTube, and occasional news reports from local media. It turned out that official accident data and statistics did not properly cover the phenomenon of wheel loss on passenger cars. A scientifically and statistically profound analysis of the real scope of the phenomenon was hence impossible, due to the lack of suitable data.

However, there are thorough investigations about loose wheels or wheel loss on heavy commercial vehicles (HCVs) in the UK from 2006, when the Department of Transport recognized a problem and investigated the scope [Ref. 1]. Japanese authorities have also investigated the phenomenon for HCVs and are currently considering mandatory preventive/monitoring measures due to an unacceptable high number of injuries and fatalities during the last years. Investigations have also been made in Canada and Finland, see [Ref. 2] for an overview. This, combined with the fact that HCVs have a higher number of wheels bolts per wheel, frequently get checked by trained drivers and wheel changes are normally done by well-equipped and trained specialists, the hypothesis that the phenomenon would be at least as common among passenger cars as among HCVs became more plausible.

NIRA decided to investigate the situation in some key automotive markets like China, USA and Japan. The study was done using a consumer survey and was carried out 2022 with around 4500 respondents in total.

The results confirmed the initial hypothesis that loose wheels or even wheel loss is not uncommon. Therefore, preventive measures and/or monitoring functions and warning systems could be beneficial for traffic safety.

However, the conducted consumer surveys did not cover the EU or any of EU's member countries, nor a country like Sweden where the climate conditions and national legislation force the majority of vehicle owners to frequently change between summer and winter wheels – which has been assumed to be a major opportunity for human error, ultimately leading to wheel loss.

In 2021 VTI (The Swedish National Road and Transport Research Institute), on behalf of NIRA, investigated the situation in Sweden based on available road accident data and insurance information. The investigation has previously not been made public, but is included in this report in appendix B. From a search in the Swedish Traffic Accident Data Acquisition database (Strada), it was estimated that passenger car wheel loss leads to 2–3 accidents with personal injury per year. These numbers are expected to be low since many accidents are not reported into the database. The number of wheel loss accidents reported to insurance companies was estimated to be 1000–1500 per year, which is in line with a Norwegian investigation of 500 wheel loss accidents per year in Norway.

The topic was then brought up in the Swedish Tire Safety Council which led to the present study and report.

5.3. Changing wheels on a passenger car

Changing wheels on a passenger car should be carried out as follows[1]:

- Remove the bolts/nuts and the old wheel.
- For both the old and the new wheel, as well as the vehicle: Clean and inspect all contact surfaces, threads (and if applicable: adapters) for wear, damage, and excessive corrosion.
- Replace damaged, worn and excessively corroded parts.
- Do not lubricate the threads or surfaces before assembly. (The reason is that on passenger cars, there is then a great risk that the bolt/nut will be pulled past the yield point of the material, which leads to damage to the threads leading to a poorly fitting bolt/nut.)
- Ensure that the bolts/nuts match the rim (cone/rounded/flat).
- Mount the new wheel and tighten the bolts/nuts in a crosswise pattern to a moderate torque, well below the recommended torque and check that the wheel sits tight and flat on the hub.
- Using a correctly adjusted torque wrench, tighten the bolts/nuts in a crosswise pattern to the torque as recommended by the vehicle manufacturer.
- Note! After 50–100 kilometers of driving, re-tighten the bolts/nuts according to the previous step.

[1] Source: The Scandinavian Tire & Rim Organization – STRO

6. Preparation & Execution

After having successfully conducted a study on road safety issues connected to caravan tires, the working group was made aware of national studies in other countries indicating that vehicles losing a wheel can be an underestimated problem and that there is no corresponding data for Sweden. Even though the topic of wheel loss is not directly related to ageing tires or tire failures, the working group decided to further investigate the topic through a consumer survey, inspired by earlier, similar studies conducted by NIRA Dynamics.

Most of the data, analysis and the present report are hence based on an online consumer survey conducted during the spring 2023.

The working group set up a detailed sequence of questions of which the majority were multiple choice. An introductory set of questions was about personal information of the respondents, to allow later comparison with reference groups.

The sequence and formulations of the questions were chosen based on experience with earlier surveys in this topic – also to allow comparability – but also to reflect the differentiation of the respondents in certain sub-groups, for example by gender, age or habits related to wheel change. In suitable cases, the respondents were given the opportunity to respond freely, which in earlier studies had proven to be a very valuable source of clarification and insight.

Suitable respondents (private car owners) were contacted through the Council's and working group's member organizations Bilprovningen (vehicle inspection company), Folksam (insurance company) and NTF (traffic safety NGO). The respondents were asked to answer a survey regarding their experience of lost passenger car wheels. There were no incentives for the respondents, other than contributing to increased road safety. The council closed the survey when more than 5 000 respondents had participated (ref. Appendix A.) The survey was conducted between March 25th and May 8th 2023.

It should be noted that informing the respondents about the purpose of the survey beforehand can lead to a bias of the group of people that accepts to participate. In this case, it is possible that people with experience of wheel loss may be especially interested to participate, and therefore making the results less representative. However, such a bias among participants is often not possible to avoid, and in this case it appears acceptable.

6.1. Gender and age

In this survey, 78 percent of the respondents were men. According to Statistics Sweden – SCB, 64 percent of the private passenger cars in Sweden are owned by males[2]. In the yearly Däckrazzia initiative in Sweden[3], about two thirds of the cars inspected out on the roads were driven by men. According to a VTI study from 2005 [Ref. 3], the average driving distances with cars in Sweden was 26 km per day for men, and 10 km for women. Women travel more as passengers, 12 km per day as compared to 5 km in the case of men. Thus, with respect to driven distance by car, 78 percent males in the survey seems to be representative. However, with respect to travelled distance within a car (as driver or passenger) men would be overrepresented in the survey.

The respondents did not present their exact age, but an extrapolation from the survey results gives a mean age of 64 years. There is no public source for the average age of the

[2] https://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__TK__TK1001__TK1001A/PersBilarA/table/tableViewLayout1/
[3] https://dackrazzia.se

private passenger car buyers or owners in Sweden, but for similar markets like Germany[4], it is between 50 and 55. An assumption is that this data is also applicable för Sweden.

The average study participant is older and more often a male than the average Swedish car owner. The age and gender in different age groups are presented in diagram 1.

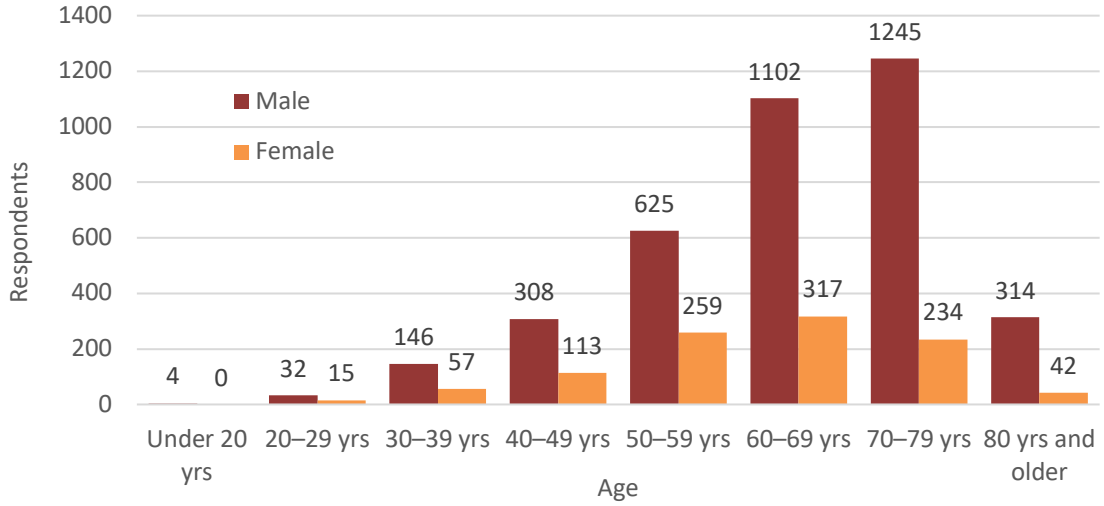

Diagram 1: Gender and age of respondents.

According to [Ref. 3] the percentage of men and women that drives a car on a daily basis is much lower for people over 64 years of age compared to younger persons, as shown in Table 1. Thus, from a driver's perspective the group of respondents are not representative with respect to age. It is assumed that this will not influence the results of the survey, but it cannot be ruled out that the driving distances or wheel changing habits of the population are affected by age.

Table 1. Percentage of men and women in the ages 18–80 years old that drive a car on a daily basis in Sweden [Ref. 3].

Age	Men (%)	Women (%)
All ages	54	34
18–25 years	46	26
26–45 years	60	45
46–64 years	61	36
64–80 years	28	11

6.2. Source of contact

The large majority or 84 percent of the 5 078 respondents joined the study through Bilprovningen's customer program. 5 percent joined through Folksam and NTF respectively and 6 percent chose the option "other" in the questionnaire.

4 https://de.statista.com/statistik/daten/studie/215576/umfrage/durchschnittsalter-von-neuwagenkaeufern/

7. Results

7.1. Wheel loss – how often?

The respondents were asked whether or not they had been traveling in a car which lost a wheel, i.e. not only a tire, but the whole tire and rim assembly.

Of all respondents, 6.3 percent, responded that they have experienced losing a wheel when traveling in a car during the last 10 years – one, two or three times or more, see diagram 3.

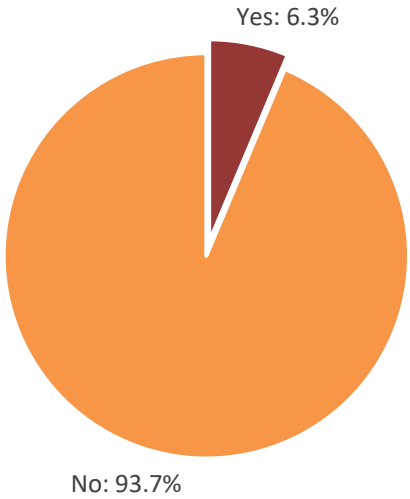

Diagram 2: Respondents who during the last 10 years were traveling in a car which lost a wheel, one or more times. N: 4,988 respondents.

The majority, 5.9 percent, had experienced a wheel loss one time during the ten years period, 0.38 percent two times and 0.06 percent three times or more. Adding all the experiences of a lost wheel during the ten years period, divided by the total number of respondents ant then divided by ten gives an estimation of that approximately 0.68 percent experience wheel loss each year. See table 2.

Of those who had experienced wheel loss whilst traveling in a car, approximately 80 percent were drivers and 20 percent passengers.

Table 2: Wheel loss during the last ten years period and extrapolation of yearly events. In the column "events", the number of respondents has been multiplied by the number of times wheel loss was experienced (in the case "3 times or more" the multiple 3 was used even though there may be more than 3 in this answer).

Wheel loss/10 years	Respondents	Share	Events	Events/year	Share events/year
1 time	294	5.9%	294	29.4	0.59%
2 times	19	0.38%	38	3.8	0.076%
3 times or more	3	0.06%	9	0.9	0.018%
Total	4,988	6.3%	341	34.1	0.68%

Extrapolating the survey results to the total passenger car population in Sweden, which was 4,98 million in 2022, is not straightforward. Multiplying the number of cars with 0.68 percent from the table would indicate a total of approximately 30,000 incidents of wheel loss annually in Sweden. That would be correct if the wheel loss experience only referred to incidents occurring with the respondent's own car, and assuming no wheel loss incidents with that car without the owner being present. Still, it is safe to assume that a vehicle owner will conduct most of the yearly milage with their own car, either as driver or as passenger. Thus, a total of 30,000 annual wheel loss incidents is probably an adequate estimation, although a potential respondent bias towards participating or gender and age distributions, are hard to quantify.

7.2. Wheel loss – consequences for traffic safety?

Of the respondents who had experienced a wheel loss, 3.0 percent stated that the latest incident caused an accident – 0.3 percent (one respondent) with injuries and hospitalization and 2.7 percent without injuries. 66 percent stated that the incident led to a certain (37 percent) or high (29 percent) risk for an accident. See diagram 4.

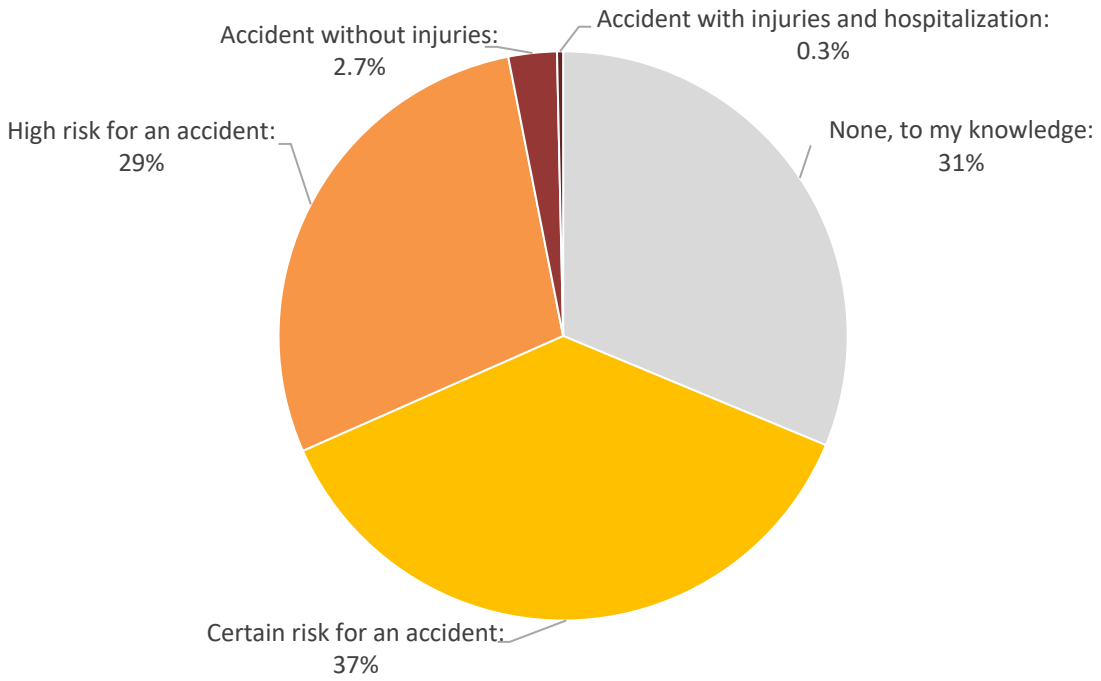

Diagram 3: Consequences for traffic safety of wheel loss, latest wheel loss event. N: 291 respondents.

7.3. Wheel loss – consequences for the vehicle?

Of the respondents who had experienced a wheel loss, 59 percent stated that, at the latest incident, the vehicle that lost the wheel suffered damages – 40 percent minor damages, 18 percent major damages and 1 percent total damage. See diagram 4.

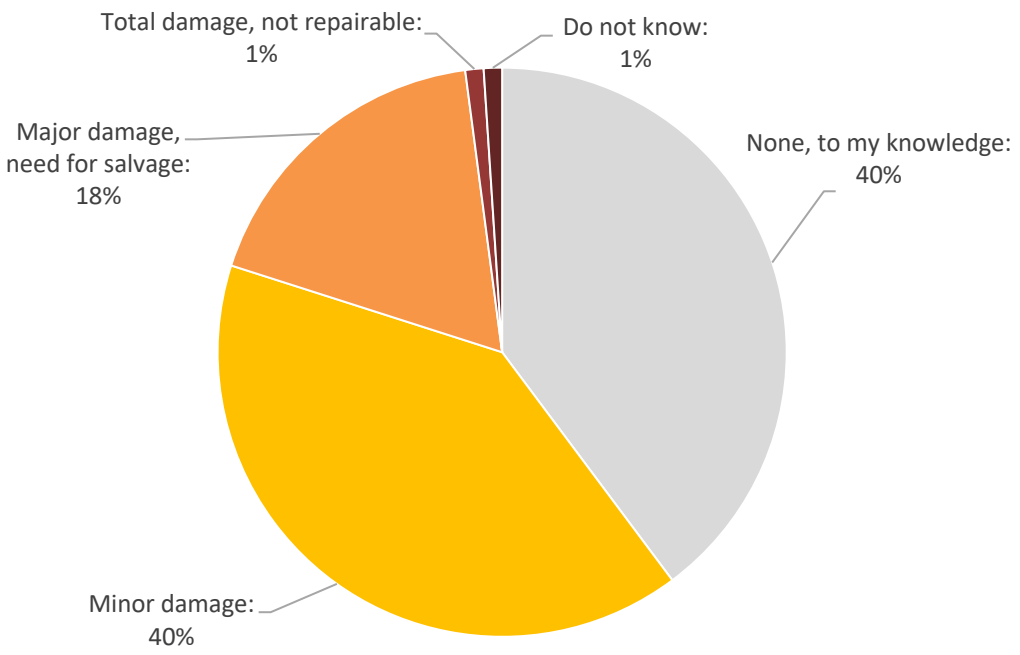

Diagram 4: Consequences for the vehicle of wheel loss, latest wheel loss event. N: 289 respondents.

7.4. Are the professionals doing a better job?

I Sweden, most car owners change wheels between seasons – to summer tires in the spring and to winter tires in the fall. Almost an equal amount of the respondents stated that they change wheels themselves as those who let a workshop do the job. Some stated that they got help from a partner/friend/colleague. See diagram 5.

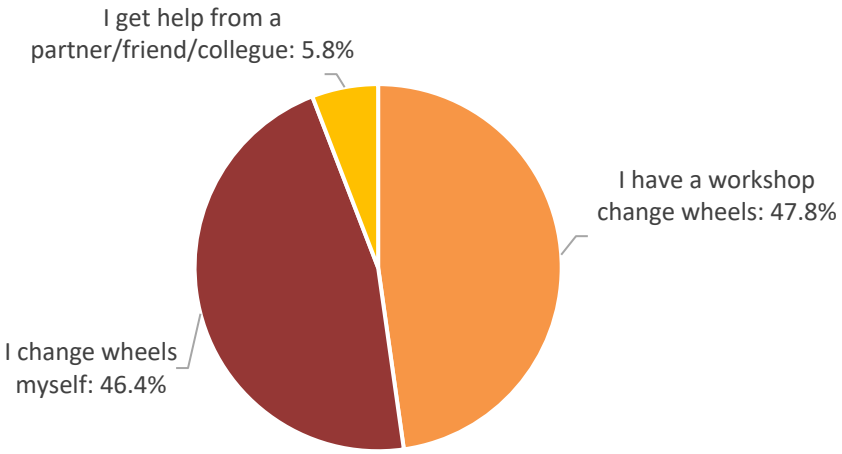

Diagram 5: Those who change wheels themselves, those who get help from a partner/friend/colleague and those who has it done at a workshop. N: 4,263 respondents.

Among respondents who change wheels themselves, 6.2 percent had experienced wheel loss one time in the past ten years. Respondents letting professionals at a workshop handle the change stated this to a somewhat lower degree (5.1 percent). The group who let a

partner/friend/colleague change the wheels had a result in between, with 5.6 percent that had experiences wheel loss. See diagram 6.

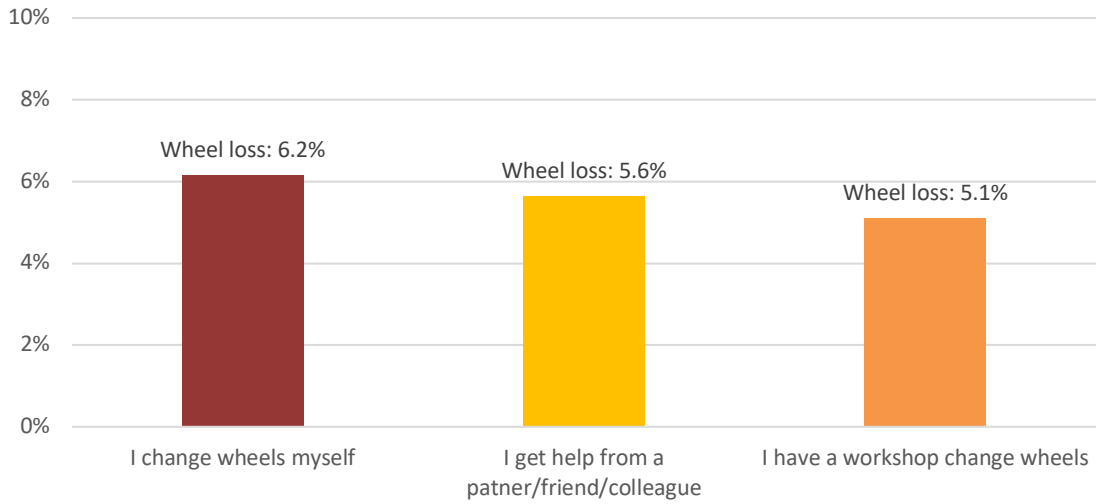

Diagram 6: Wheel loss the past ten years, for those who let a workshop change the wheels (n: 2,174 respondents), for those who get help from a partner/friend/colleague (n: 255 respondents) and for those who change the wheels themselves (n: 2,112 respondents).

7.5. Does the use of a torque wrench make any difference?

Among those who change wheels themselves, 26 percent state that they always use a torque wrench and 8 percent state that the use a torque wrench sometimes. See diagram 7.

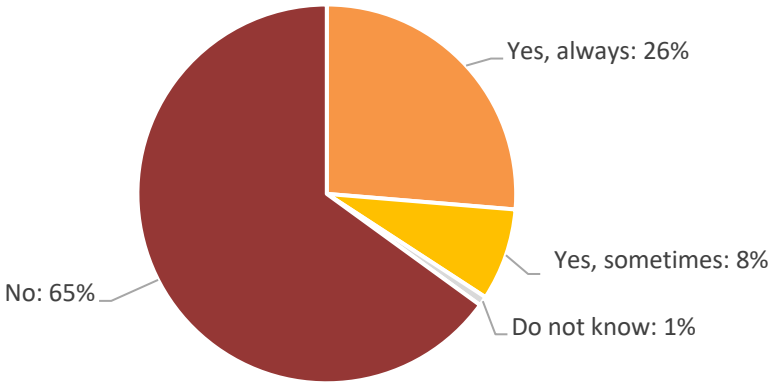

Diagram 7: Use of torque wrenches among those who change wheels themselves. N: 2,109 respondents.

There is, however, no significant difference in how many of the respondents that had experienced wheel loss in the group who always uses a torque wrench (6.9 percent), compared to the group that stated that they do not use a torque wrench (6.4 percent). See diagram 8.

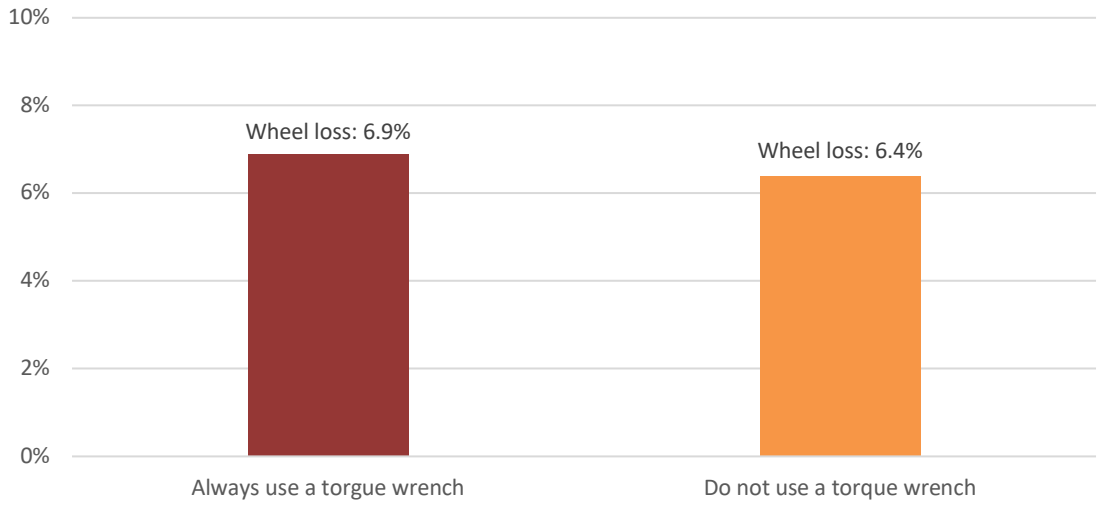

Diagram 8: Wheel loss the past ten years, for those who always use a torque wrench (n: 552 respondents) and for those do not use a torque wrench (n: 1,365 respondents).

7.6. Is the use of thread lubrication a risk?

It is not recommended to use thread lubrication when changing wheels on passenger cars. Even so, a majority of the respondents who change wheels themselves apply thread lubrication (58 percent). See Diagram 9.

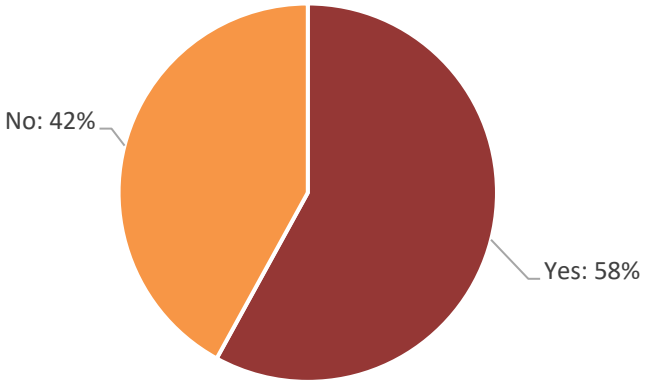

Diagram 9: Practice of thread lubrication among respondents changing wheels themselves. N: 2,107 respondents.

There is, however, no significant difference in how many of the respondents that had experienced wheel loss in the group who apply lubrication to the threads (6.1 percent), compared to the group that do not (6.4 percent). See diagram 10.

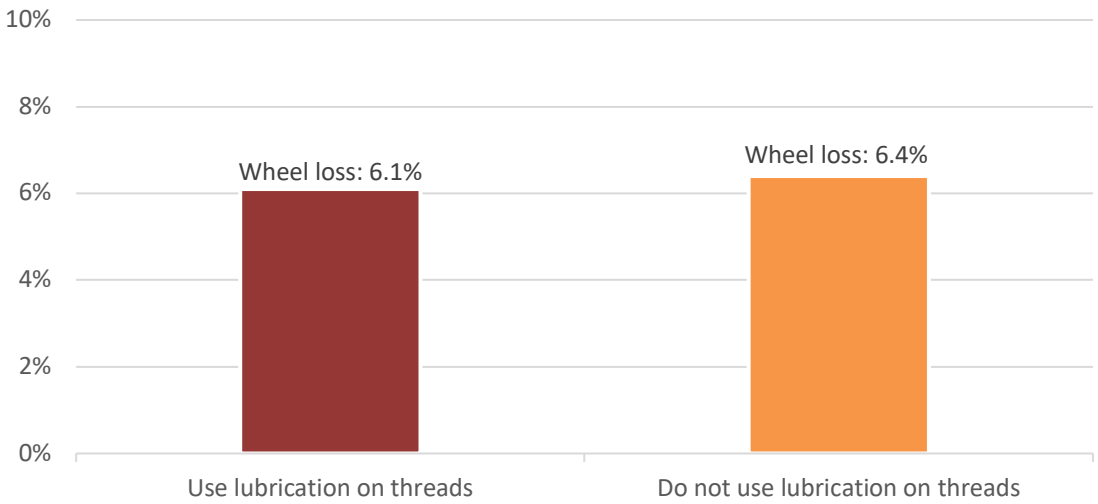

Diagram 10: Wheel loss the past ten years, for those who use lubrication on threads (n: 1,211 respondents) and for those do not use lubrication on threads (n: 880 respondents).

7.7. Is surface cleaning important?

The majority, 83 percent, of the respondents who change wheels themselves clean the surfaces, including threads, before mounting the wheel to the car. See diagram 11.

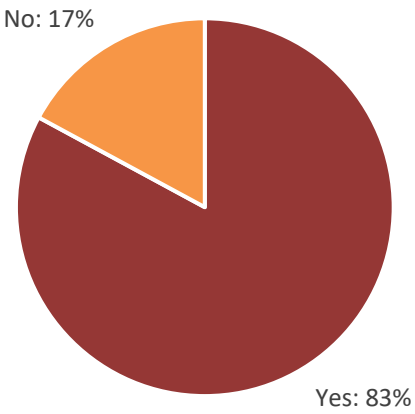

Diagram 11: Practice of cleaning of surfaces, including, threads, before mounting the wheel to the car. N: 2,098 respondents.

A higher percentage of those who do not clean surfaces, including threads, reported that they had experienced wheel loss the past ten years (7.5 percent) compared to those who clean surfaces (5.9 percent). This is equivalent to a 27 percent higher risk of wheel loss if you do not clean the surfaces prior to mounting the rim to the car, compared to if you clean the surfaces. See diagram 12.

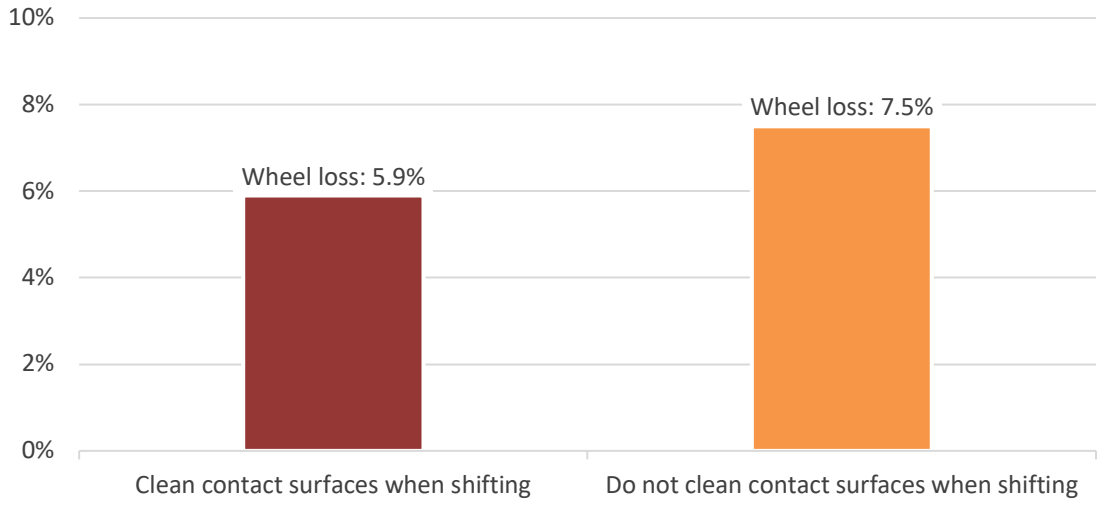

Diagram 12: Wheel loss the past ten years, for those who use clean surfaces, including threads, (n: 1,739 respondents) and for those do not (n: 359 respondents).

7.8. How common are loose nuts and bolts?

A significant share (28 percent) of the respondents had detected one or more loose bolts or nuts at least once during the past ten years, see diagram 13. The means of detecting the loose bolts/nuts were mainly when re-tightening after changing wheels (40 percent) and/or dissonance when driving (42 percent), see diagram 14.

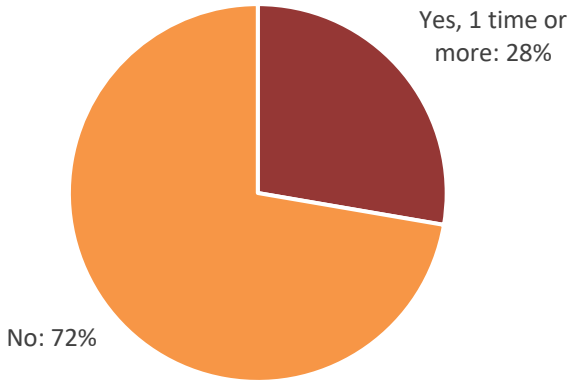

Diagram 13: Respondents who during the last 10 years detected one or more loose bolts or nuts at least once. N: 4,681 respondents.

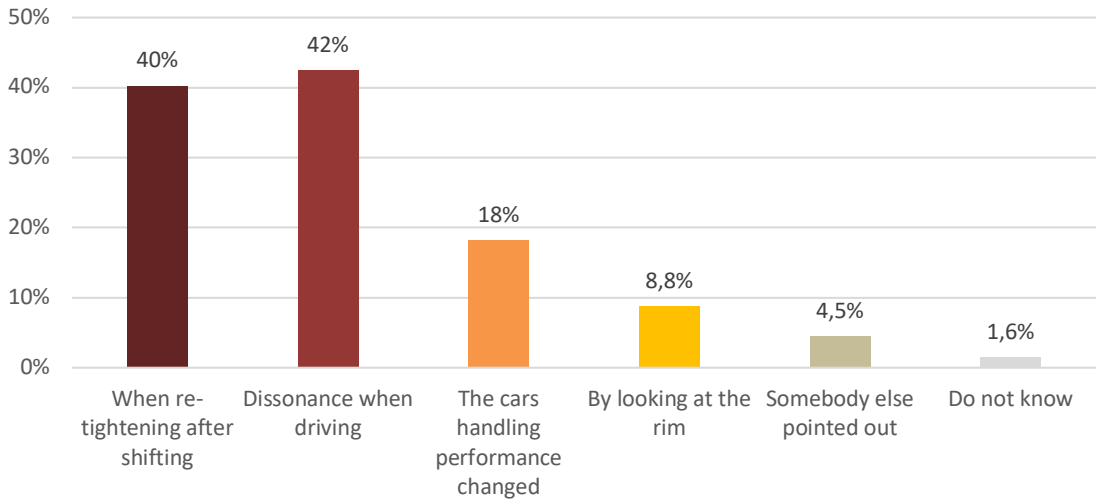

Diagram 14: Means of detecting loose bolts or nuts. Multiple answers possible. N: 1,279 respondents.

Nearly half of all respondents (48 percent) answered that they would appreciate a function that gives a warning when a wheel is not attached properly. One third (33 percent) answered that they maybe would appreciate such a function. In the group with respondents who had been in a car the past ten years losing a wheel, the share that answered "maybe" was reduced with almost ten percent units, in favor of the answer "yes". The share that answered that they would not appreciate a system warning for lose wheels ("no") was 12 percent, both among all respondents and in the group with respondents who had experienced wheel loss. See diagram 15.

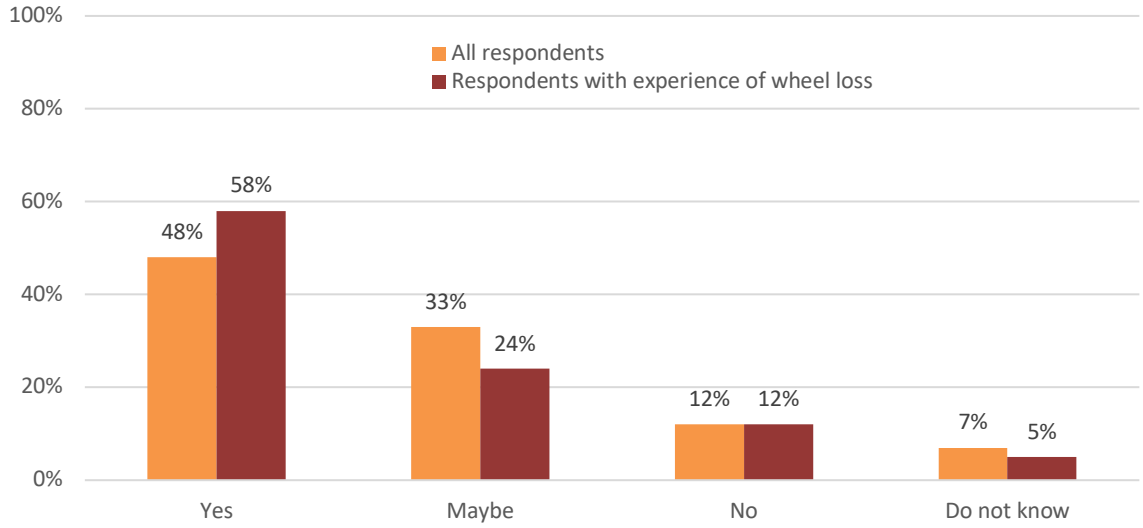

Diagram 15: Answer to the question: "Would you appreciate a system that gives a warning when there is one or more lose wheels on a passenger car?" For all respondents (n: 4,832 respondents) respectively for those who has experienced wheel loss (n: 277 respondents).

7.9. Free Comments

The respondents were allowed to add free text to some answers. In many cases, this information was helpful to get insight in the respondents' experiences, e.g.:

- Many respondents had experienced lose bolts or nuts, that were detected before an actual wheel loss.
- There were several respondents who have experienced wheel loss on their own cars but wrote that it was more than ten years ago and hence correctly answered the respective question with "no".
- Use of torque wrenches is often rejected as "experienced mechanics feel the right torque".
- Several respondents reported technical problems like damaged threads, loose bolts or nuts or even loose wheels after wheel change by workshop, which made the respondents change wheels themselves again.
- Lubrication of bolts/nuts gets justified with easier loosening when it is time for the next changing.

8. Discussion

In this section, topics are addressed which are based on assumptions or raise further questions.

8.1. Number of accidents, injuries and fatalities caused by wheel loss

The TRL study on Heavy Commercial Vehicles (HCV) I Great Britain (see section 5.2) shows that 33 percent of all wheel detachments lead to accidents without injuries, another 7 percent to accidents with injuries and another 2 percent to accidents with fatalities. Table 3 below compares these figures with the present study results.

Table 3: Accident and injury rates after wheel losses compared between the TRL HCV study from the UK (2006) [1] and the present study.

Study	Wheel loss, no traffic accident	Wheel loss, traffic accident with damage only	Wheel loss, traffic accident with injuries	Wheel loss, traffic accident with fatalities
TRL HCV 2006, UK [1]	58%	33%	7%	2%
Present study (see Diagram 3)	97%	2.7%	0.3% (very uncertain number)	-

It should be stressed that the estimate of the share of passenger car wheel loss accidents that leads to personal injury from the present study is rather uncertain. The number comes from the answer of one respondent out of 300, which leads to very large statistical uncertainty (the 95 % confidence interval is between 0 and 1.6 %). Assuming 30 000 wheel loss incidents per year, 0.3 % would imply around 100 accidents with personal injury every year in Sweden. This can be compared to the 2–3 injured people per year from the Strada investigation carried out by VTI (see appendix B). Thus, the real share of passenger car wheel loss accidents that leads to injury is probably closer to 0.01 %.

Interestingly, the estimated 2.7 % of passenger car wheel loss that leads to accidents with damage only would imply around 900 insurance cases every year, assuming 30 000 wheel loss incidents per year. This corresponds very well to the 1000 – 1500 insurance cases due to wheel loss estimated by Trygg Hansa (see appendix B).

Wheel losses from HCV in the UK lead much more often to traffic accidents than from passenger cars in Sweden, according to this study, and the consequences are much more severe, which appears plausible. Factors which are supposed to play a role are differences in wheel size, mass and kinetic energy, general traffic density and right- and left-hand traffic. This should be investigated further based on actual accident data once such data becomes available.

8.2. Does having the wheels exchanged by a professional workshop reduce the risk of losing a wheel?

Respondents changing themselves have circa 20 percent higher risk of losing a wheel than those letting professionals handle the wheel change, see Diagrams 5 and 6, with those who get help from friends or relatives in between. Taking into account that workshop staff is trained, educated, experienced and has access to proper tools and information, the difference is surprisingly low. This is also supported by anecdotal evidence from several free

text responses stating that vehicle owners have become self-changers after loose wheel experiences when having the wheels changed by a workshop. Time pressure in the workshops during changing season in the fall and spring, is surely an explanation, though not a justification to abandon safety relevant routines. Better training, education and optimized workshop routines could be a way to ensure professional work even under time pressure and can also be seen as an opportunity for the workshops to re-gain trust and hence bring back former customers.

8.3. Effectiveness of the individual precautions?

8.3.1. Re-tightening

The results of the present study do not provide a definitive answer on the effectiveness of re-tightening. The study does, however, show that many lose bolts or nuts are detected through re-tightening. It appears also common sense from a mechanical perspective that many of the common mistakes during the initial wheel change will likely be compensated for when re-tightening. Conversely, omitted re-tightening requires a perfect wheel change procedure to achieve safe results. Further investigations should also cover the percentage of workshop customers who return to the workshop for re-tightening or who re-tighten themselves.

8.3.2. Use of torque wrench

Using a torque wrench, even a cheap or poorly maintained one, will reduce the variation in tightening torque. But if the widely varying torque recommendations [Ref. 4] are not followed or other mistakes are made, the benefit is limited. The present study results indicate that using a torque wrench adjusted to the recommended torque makes an already good wheel change better, but it can hardly compensate for other, more common mistakes.

8.3.3. Thread lubrication

For HCVs (Heavy Commercial Vehicles), some manufacturers recommend thread lubrication, others do not. The results from the UK study mentioned above [Ref. 1] indicate that thread lubrication, if using a suitable grease for already used HCV bolts and nuts, has even positive effects. This is in line with the results of this study, where thread lubrication at least does not show any negative effects. However, until further research is done for passenger cars, workshops and drivers should stick to the general recommendation of the passenger vehicle manufacturers not to lubricate the threads.

References

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[4] Torque settings for wheel bolts/wheel nuts, Continental Tires, https://blobs.continental-tires.com/www8/servlet/blob/1080706/71cfb5154e939befc74980e98145e9a3/download-torque-settings-data.pdf

[5] Calculator.net, Sample Size Calculator: https://www.calculator.net/sample-size-calculator.html

[6] https://sakochliv.se/2020/10/28/trygg-hansa-varnar-att-hjulen-kan-ramla-av-efter-dacksbytet/

[7] https://www.dackavisen.se/hjul-som-lossnar-orsakar-skador-for-10-miljoner/

Appendix A – Statistical base: Sample sizes

In accordance with [Ref. 5], the target sample size for the key question, whether or not one has experienced wheel loss, had been estimated according to

$$n \geq \frac{z^2 \cdot p \cdot (1-p)}{e^2}$$

with n = sample size
z = confidence level (1,96 for 95% confidence)
p = (assumed) probability of the qualitative property (0,05)
e = target error or resolution (0,01 for 1%)

More specifically, the investigated guiding property is the experience of a lost wheel on the participant's car during the last 10 years. The limitation to the last 10 years was introduced to better enable a comparison with accident, injury and fatality rates which are typically defined and published on an annual base. For simplification reasons, it is assumed that the vast majority of respondents has not experienced a lost wheel and otherwise, in most cases only once and hence the expected small number of respondents with multiple lost wheel experiences is neglected for this estimation. The guiding property is therefore a qualitative one with two possible options and an initially assumed probability of p = 5% (or 0,05) for a lost wheel experience and hence a probability of 1-p = 95% (or 0,95) for no lost wheel experience. The assumption is based on outcomes from the NIRA Dynamics survey conducted in USA, China and Japan, where 6 to 21 % of the respondents had been in a vehicle that lost a wheel. This then gave a target minimum sample size of n = 1 825.

Due to the character of the survey covering multiple further properties beyond the lost wheel experience, it was expected that there would be several sub-populations among the respondents with significantly smaller sub-sample sizes. Typical examples are those who have experienced a lost wheel at least once and changed their wheels themselves, or to name an even smaller sub-population, those who have experienced a lost wheel which also led to an accident with injuries. It was therefore suggested to increase the target sample size to n = 5 000 as a reasonable compromise between statistical accuracy and relevance on one side and effort and duration on the other side.

This should result in an expected sub-population of around 250 respondents who had a lost wheel experience. From the UK study on HCV [Ref. 1], a coarse assumption could be derived that around 60 percent of lost wheel cases do not lead to accidents (or collisions), another 33 percent to collisions w/o injuries or fatalities, 7 percent to collisions with injuries and 2 percent to collisions with fatalities, see table 2. It is however not possible to estimate the expected percentages of accidents leading to personal injury from lost passenger car tires based on statistics from heavy vehicle wheel loss. Thus, it is hard to estimate the sample size needed to accurately estimate the risk of personal injury from the survey.

Appendix B – VTI investigation of detached passenger car wheels

An investigation of detached passenger car wheels was carried out by Jenny Eriksson and Mattias Hjort at VTI during the fall of 2021 on behalf of NIRA Dynamics. The results were reported directly to NIRA and has not been published elsewhere. The purpose of the study was twofold:

1. To search in the Swedish Traffic Accident Data Acquisition database (Strada) to see if there are any indications of personal injuries because of detached passenger car wheels.
2. Contact the major Swedish insurance companies to get an overview estimation of how many insurance cases per year that involves wheel detachment.

Accidents with injuries

The Strada database is an accident database where the Swedish police and medical care report accidents and injured road users. The following types of accidents are reported:

- Police: Road traffic accidents involving personal injury. Nationwide in Strada since 2003. The reporting is not complete, and only covers what the police are aware of. Accidents where there is a suspicion of a crime are extra prioritized.
- Medical care: All of Sweden's emergency hospitals report information on people who have sought care for an injury in a road traffic environment. Nationwide in Strada since 2016. Incomplete reporting due to lack of time among medical staff, or due to that some injured people visit a health center instead of emergency hospital. Reporting to the database also requires the patient's consent.

The VTI search covered the entire database during the ten years period 2011 to 2020. Only accidents involving at least one of the following vehicle types were considered: passenger car, truck/lorry or bus. In total 198 638 accidents were included. To get an estimate of the order of magnitude a broad first search was conducted, see Table B2.

Table B2. Results from the broad search.

Search phrase (Swedish)	Search phrase (translated to English)	Number of matches / accidents	Comment
”tappa” *de, *t	“lose”,”lost” (singular and plural)	8470	Often in the meaning of lost control of the vehicle
”hjul” *et, *en	“wheel” (singular and plural)	3966	Often describing wheel lock
”däck” *et, *en	Tire (singular and plural)	2898	Often describing a winter tire
”lossa”, ”lossna” *de, *t	“loosen”, ”come loose” (present and past tense)	394	Not so commonly occuring

After that, a more detailed search was carried out, containing the search phrases listed in Table B3. That resulted in 152 matches, out of where some accidents were found twice. A thorough investigation of the supplied information on these matches resulted in the summary presented in Table B4.

Table B3. Results from the detailed search.

Search phrase (Swedish)	**Search phrase (translated to English)**	**Number of matches / accidents**	**Comment**
”fälg”, ”hjulet på bil”	“rim”, “car wheel”	46	
”bildäck”	“car tire”	64	
”hjulbult”	“wheel bolt”	6	
”tappa hjul”, ”tappade hjul”, ”tappat hjul”	“lose wheel”, “lost wheel”, “lost wheels”	9	
”tappar hjul”	“losing wheel”	1	
”lossa hjul”, ”lossade hjul”, ”lossnat hjul”	“loosen wheel”, ”loosened wheels”	0	No hit
”lossna hjul”, ”lossnat hjul”, ”lossnande hjul”	“wheel come loose”	0	No hit
”hjul lossade”, ”hjulet lossnade”, ”hjulen lossnade”	“wheel came loose”, “wheels came loose”	9	
”löst hjul”	“loose wheel”	1	
”rullande hjul”, ”rullat hjul”, ”rullande däck”, ”rullande bildäck”	“rolling wheel”, “rolled wheel”, “rolling tire”, “rolling car tire”	0	No hit
”tappa däck”, ”tappade däck”, ”tappat däck”,	“lose tire”, “lost tire”, “lost tires”	11	
”tappar däck”	“losing tire”	5	
”lossa däck”, ”lossade däck”, ”lossnat däck”	“loosen tire”, “loosened tire”	0	No hit
”lossna däck”, ”lossnande däck”, ”lossnat däck”	“tire came loose”	0	No hit

Table B4. Summary of the detailed search.

Lost wheel on a passenger car?	No personal injury	Minor accident (ISS 1–3)	Moderate accident (ISS 4–8)	Total
Yes	4	11	3	18
Yes, collides with a rim from an un-specified vehicle		3		3
Difficult to assess/ not enough information	3	9	2	14
No	8	68	12	88
No, the rear axle broke		1		1
No, passenger car trailer, including caravan		3		4
No, from truck trailer	2	6	1	9
No, truck lost a wheel		6	1	7
Total	17	108	19	144

In total, out of around 200 000 reported accidents, 35 accidents were found that could stem from passenger car wheel loss. 28 of these resulted in personal injury. In almost half of these cases however, there was not enough information to with certainty establish that a lost passenger car tire was the cause of the accident. It can be concluded that at least 17 accidents resulting in personal injury is related to a lost passenger car wheel, which amounts to around 0.01 % of all reported accidents. This corresponds to 2 to 3.5 accidents per year.

Thus, the number of confirmed yearly accidents that lead to personal injury is quite low. However, since the search was rather limited, and because not all accidents are reported to Strada, there is reason to believe that the actual numbers may be higher than this.

Examples of descriptions where definitive conclusions could be made, and cases that were considered inconclusive are shown in Table B55.

Table B5. Examples of descriptions.

Confirmed loss of wheel leading to the accident	
Yes	Run-off road due to lost wheel.
Yes	Passenger car 1 is driving on the road when it suddenly loses its left front wheel. The car skidded and flipped around a couple of times on the road until it finally ended up upside down in the ditch.
Yes	Passenger car 1 drives to the side after the front wheel comes off. Passenger car 2 steers to avoid it and is then hit by truck 1.
Uncertain	A passenger car has crashed into the barrier on the right side after a curve and lost the wheel.
Uncertain	Passenger car 1's driver hears a bang and is then heading into the wire barrier. Parts from passenger car 1 cross over onto the opposite carriageway. A rim with strut goes under passenger car 2. Passenger car 1 then stops 125 meters from the spot where it hit the wire barrier

Insurance cases

According to statistics from Svensk Försäkring, the number of passenger cars with a traffic insurance 2019 was 4.8 million, and the number of cars with engine insurance was 5 million. 1.2 million accidents were reported during 2019, where the total amount of damage paid was 9.5 billion SEK. The damage paid for the average accident was 8,000 SEK.

The market shares among the Swedish insurance companies in 2021 are listed in Table B66 below. The main part of the market (90%) is divided between four companies: Länsförsäkringar, If Skadeförsäkring, Folksam and Trygg Hansa.

Table B6. Market shares of insured passenger cars during quarter 2, 2021. Source: Svensk Försäkring.

Company group	**Company**	**Number of insured passenger cars**	**Market share**
Länsförsäkringar	LF gruppen	1 721 987	34%
If Skadeförsäkring	If Skadeförsäkring	1 354 821	27%
Folksam	Sak & Tre kronor	948 460	19%
Trygg-Hansa	Trygg-Hansa	490 563	10%
Moderna	Moderna, filial	169 328	3%
Dina federationen	Dina federationen	157 988	3%
ICA Försäkring	ICA Försäkring	101 168	2%
Gjensidige	Gjensidige filial	96 404	2%
Protector	Protector	64 044	1%
		5 104 763	100%

According to the two companies with the largest market share, Länsförsäkringar and If Skadeförsäkring, it is not possible to find accidents related to wheel loss through a

database search. The third company, Folksam, was not considering wheel loss to be a prioritized issue and did not have any statistics related to this.

Trygg-Hansa, with a market share of 10%, estimated in 2020 that 100–150 of their passenger car customers will experience wheel loss every year [Ref. 6]. Extrapolating those numbers to the entire passenger car market, would imply 1,000 to 1,500 accidents because of wheel loss yearly in Sweden.

A local part of Länsförsäkringar, LF Östgöta, did have a database that could be searched for wheel loss accidents. Their market share is very small, so extrapolating their data to the entire country would lead to large uncertainties. Still, doing so results in 600–800 wheel loss accidents per year, which is of the same order as the Trygg-Hansa estimation. The total cost for the insurance companies was estimated to be 6 to 12 million SEK.

In Norway, it has been estimated that almost 500 passenger car owners experiences a wheel loss that is reported to an insurance company every year [Ref. 7]. The average damage cost per vehicle is 20,000 NOK, leading to a total cost of 10 million NOK every year. Considering that the Swedish passenger car fleet is roughly twice the size of the Norwegian fleet, the Trygg-Hansa estimation of 1,000 to 1,500 accidents per year in Sweden seems reasonable.