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Lane filtering in Luxembourg

An ex-ante evaluation of legalising lane filtering for motorcyclists

VAS institute

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Summary

Luxembourg is a country with a very specific traffic situation, due to its local (national) traffic and a high proportion of transit traffic. This creates, in addition to congestion as a result of a crash, heavy structural congestion. Motorcycles are able to escape this, since they are able to ride between slowly moving or stand-still vehicles (i.e. lane filtering). While lane filtering is legal and common practice in countries such as the Netherlands (since 1991) and Belgium (since 2011), lane filtering is forbidden by law in Luxembourg, Germany and France. Nevertheless, lane filtering is mentioned by experts to be common practice in Luxembourg.

The country of Luxembourg considers a legalisation of lane filtering, given the proclaimed benefits. Moreover, the country believes that a legalisation can be beneficial since it allows for the regulation of the practice. However, counterarguments and concerns are also raised, such as: an influence on rescue lane compliance by other drivers, an increase in motorcycle crashes, and negative attitudes towards lane filtering motorcyclists. As a result, this study was performed to objectively investigate the possible effects of a legalisation of lane filtering on traffic flow, rescue lane impact, crash risk, and attitudes and behaviour of other road users.

This study presents a benchmark of previous studies and expert opinions to gather more insights into lane filtering and its impact on the compliance of the rescue lane. Next, a traffic flow effect study was carried out. In addition, a crash risk modelling and literature consultation on crash risk was performed to better understand the possible link between crash and lane filtering. Lastly, a questionnaire study was conducted to gain insights on attitudes and behaviours towards lane filtering and compliance with the rescue lane.

This study found, based on monetary and travel time gains, that the positive traffic flow effects over the whole network as a result of legalising lane filtering are founded. However, the effect was found to be small (i.e. 1.8 minutes for motorcycles, and 2.1sec for cars when the knock-on effect is ignored for a trip of 20km on the average Luxembourgish highway network). In fact, the largest benefits are shown for motorcyclists in specific situations with heavy congestion (i.e. 16 minutes time savings on a 20km congested trip). While the effects can be positively impacted by an increased number of motorcyclists in the vehicle fleet, the total effects on traffic flow for all road users can be considered as marginal. Additionally, positive effects can be countered by an additional increase in traffic (i.e. as a result of latent demand).

Despite the believe of an increased crash risk, there is no evidence based on our crash modelling, that legalising lane filtering increases the risk on motorcycle highway crashes. Nevertheless, facilitating an increase of motorcycling – regardless the measure – could potentially result in an increase in motorcycle crashes as a direct effect of higher exposure. However, this is not a direct effect of lane filtering.

Lastly, the mere presence of motorcyclists filtering between lanes, wasn't found to impact compliance towards the rescue lane. It could be determined that national differences play the largest role in performing more appropriate behaviour. Based on the results, an assumption is made that the history in terms of regulations in a country (i.e. the rescue lane concept is longer present in Germany and Luxembourg compared to Belgium and France), leads to a large impact in terms of respect and appropriate behaviour towards the rescue lane. The importance of appropriate behaviour towards the rescue lane (i.e. the urge to comply to the regulation), seems to outweigh possible actions in relation to the behaviours performed by others. Lane filtering by itself, can therefore not be considered as a facilitator of unwanted behaviours performed by others. While lane filtering was found to be a familiar practice by other road users, correct knowledge on the behaviour was, however, found to be an issue. In general, support and knowledge of lane filtering tends to be low, yet higher in countries where lane filtering is legally allowed. In general, indifference towards lane filtering was observed. However, opinions of Luxembourgish and German drivers were found to more often oppose lane filtering. Dangerous behaviours of other road users towards motorcyclists were found to be largely absent.

It can therefor be concluded that the legalisation of lane filtering does not lead to negative behavioural effects. On the other hand, the often proclaimed beneficial traffic flow effects also tend to be marginal for the whole network, while largely beneficial for the riders themselves, especially in heavy congestion situations. Lane filtering can be considered as a benefit for motorcyclists who safely perform the behaviour, to improve rider comfort, and aid efficient use of the road network.

It should be noted, that lane filtering has to be considered by riders as a possibility, and not a right, to avoid audacious behaviours (e.g. riding with high speeds, honking or revving the engine when no space is available, etc.) . On the other hand, correct knowledge, communication, and training are essential elements to increase mutual understanding and safe behaviour from all road users.

1 Introduction

1.1 Scope

The Grand Duchy of Luxembourg (hereafter referred to as Luxembourg), is a country with a very specific traffic situation, consisting out of local (national) traffic as well as a high proportion of transit traffic. This tends to create heavy congestion on the Luxembourgish highways, especially in the case of a heavy crash. Not only does it impact all road users directly in the traffic jam, it also leads to an indirect impact on the country itself (e.g. high costs, loss of productivity, pollution, etc.) .

Motorcycles are very popular and one of the many reasons for them to be used, next to leisure activity, is their flexibility in traffic. Often, when cars are stuck in a traffic jam, motorcyclists manage to ride between two lanes and pass the traffic jam (hereafter referred to as 'lane filtering'). While legal and common practice in countries such as the Netherlands (since 1991) and Belgium (since 2011), it is forbidden by law in Luxembourg. In fact, Luxembourg is not the only country currently prohibiting this behaviour, also in Germany and France for example, lane filtering is illegal.

Nevertheless, lane filtering is common practice in many countries, including Luxembourg. This means that motorcyclists accept the risk on a fine or that the police tolerates the behaviour even though technically it is not legally allowed. Matter of fact, it is not possible to regulate the behaviour (e.g. impose training, promoting safe lane filtering) when the behaviour itself is completely prohibited by law.

1.1.1 Definition "lane filtering"

In this report the term "lane filtering" is used to describe the following behaviour:

Motorcycle riders who overtake other motor vehicles, in stopped or slow-moving traffic on a highway, only between the two most-left lanes, while obeying the legal speed limit on the road (or further defined speed limit by national authorities relative to this behaviour).

Lane filtering should be differentiated from other illegal behaviours, such as:

- slaloming between vehicles at higher speeds (sometimes also called weaving)
- overtaking vehicles on the left hard shoulder
- overtaking vehicles on the breakdown lane
- overtaking vehicles on the right
- filtering between vehicles as intended between the two-most left lanes, but at too high speeds

Figure 1 illustrates the lane filtering concept, where the red arrows represent a wrong performance of lane filtering.

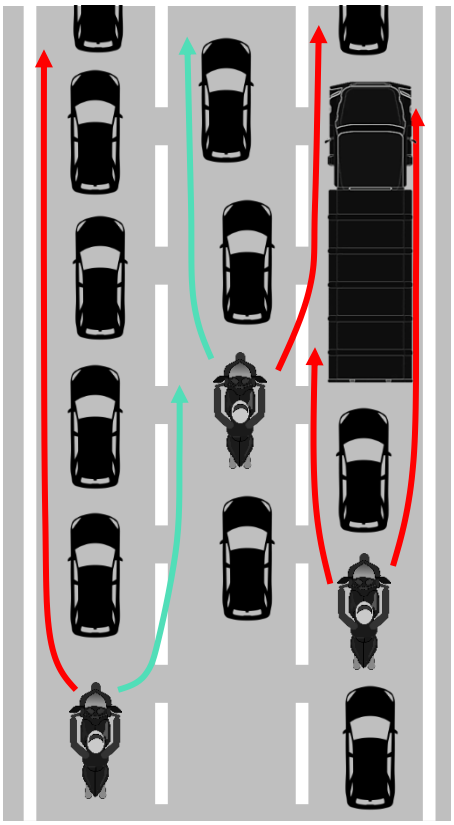

Figure 1: Illustration of lane filtering through a legal perspective

However, what is considered as "lane filtering" in this study, is also regularly called "lane splitting". Even though both terms tend to agree on the same behaviours, the terminology differs. To add, sometimes a differentiation is even made between legal (i.e. keeping to the rules) and illegal (i.e. faster or with a larger difference in speed than allowed) "lane filtering" or "lane splitting".

In most countries no generally accepted definition or terminology for lane filtering behaviour is present. In France, for example, the term used for "lane filtering" on highways is called "la circulation inter-files", while the term "la remontée de file" is used for lane filtering in urban environments to move to the front of a cue at traffic lights.

In Germany, lane filtering is not allowed, which is reflected in the absence of a specific term for it. Mostly it is called "vorschlängeln" or "vordrängeln" which means as much as jumping or cutting the queue.

1.1.2 Objective

This study was performed since Luxembourg, through the Ministry of Mobility and Public Works, sought information about the likely consequences of legalising lane filtering, and more specifically:

- Which reasons have motivated countries to legalise or not legalise lane filtering?
- To what extent does lane filtering increase crash risk?
- To what extent does legalising lane filtering impact traffic flow?
- To what degree is a legalisation of lane filtering for motorcyclists accepted by other road users?
- In order to filter between lanes, motorcyclists would probably make use of the rescue lane. Which effects on driving behaviour are to be expected from other road users? (i.e. spill-over effects)

1.1.3 Methodology

To answer these research questions, a multimethod study was performed by means of the following design:

- A crash risk study based on Belgian crash data before and after the legalisation of lane filtering in 2011. The situation in Belgium is estimated to be a good predictor for Luxembourg due to the legalisation of lane filtering in 2011 and the presence of a rescue lane.
- A modelling study tailored to calculate the mobility effects of legally allowing lane filtering on the Luxembourgish road network.
- A questionnaire study created to determine the acceptance of lane filtering by other road users, and the possible impact on the rescue lane in Luxembourg.
  - Performed in four countries to take into account transit and abroad traffic to Luxembourg.
    - Nationally representative sample of respondents in Luxembourg
    - Nationally representative sample of respondents in Belgium
    - Sample focussed on Rheinland-Pfalz and Saarland in Germany (close regions to Luxembourg)
    - Sample focussed on Grand Est in France (close region to Luxembourg)
- A benchmark study based on:
  - A literature search on the topic of lane filtering
  - Structured interviews with experts from different countries (mentioned here after)

Luxembourg

- Mr Jean-Claude Juchem, Mr Daniel Krieg (Maison du motard)
- Mr Paul Mangen (Ministère de la Mobilité et des Travaux publics - Administration des ponts et chaussées)
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The Netherlands

- Mr Dolf Willigers, Mr Wim Taal (FEMA, Motorplatform)

Austria

- Mr Martin Winkelbauer, Mr Klaus Machata (Kuratorium für Verkehrssicherheit)

1.2 Luxembourg

1.2.1 Traffic situation

Luxembourg has a very specific traffic situation.

The country is only 50 km from East to West, and about 80 km from North to South. The whole highway network consists only out of 170 km of road. The density of exits/entries is high (about every three km) and there are hardly any long stretches where traffic flows without weaving of incoming and leaving vehicles.

The Luxembourg highways supports four types of traffic:

- Transit: many trans-European routes run through Luxemburg. There are thousands of trucks and cars going through Luxembourg every day
- Commuters: There are some 180,000 commuters who live in DE, FR or BE and travel to/from Luxembourg every day.
- Holiday traffic: as part of the Route du Soleil, big traffic jams rise whenever vacation starts in neighbouring countries and states.
- Within country traffic: the ring around Luxembourg is used as a City Highway by many, entering and exiting the ring within short distances.

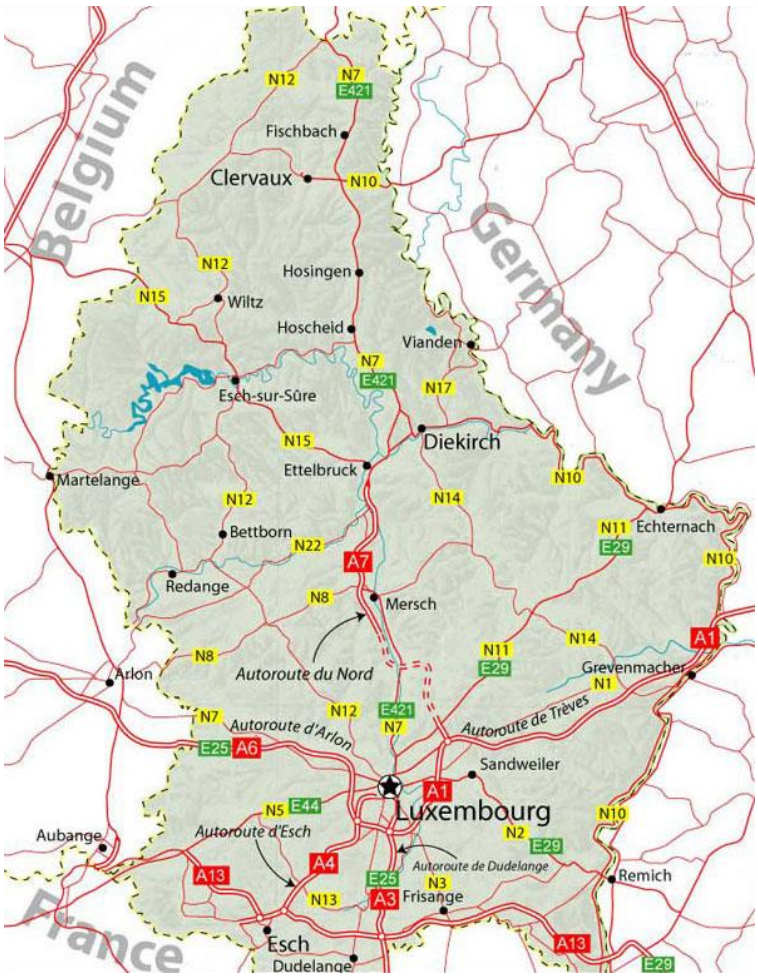

Figure 2: Highways in Luxembourg

It is essential to realize that the largest part of traffic in Luxembourg does not consist of people living in Luxembourg, but from road users abroad, such as Germany, France, Belgium, The Netherlands, and even the UK. Also a considerable amount of truck drivers from Eastern and Southern Europe are present on the Luxembourgish highway network. This results in not respecting traffic rules by drivers, possibly because "local rules" are unknown. Since drivers often apply, not thoughtfully, the rules of their own country to the situation in Luxembourg, this can become a problem particularly in those situations where laws differ between countries. Examples of this are the rescue lane, and lane filtering, which will be discussed in further sections in this report. Additionally, it also leads to a huge challenge in terms of communication

Furthermore, this effect can be directly paired with the highways in Luxembourg: the A7 is mostly used by people living in Luxembourg; the A3 and A4 are mostly used by commuters from France; the A6 is mostly used by commuters from Belgium; and the A1 and A13 are mainly used by commuters from Germany. Between these highways, different behaviours of drivers are observed, which is thought to be linked to the country of origin of the drivers. The mentioned highways can be found in figure 2.

This also applies to (touristic) motorcycling, which is very popular in Luxembourg. In the spring and summertime, the police regularly has to request support in the north of the country from their colleagues from Germany, The Netherlands, and Belgium to conduct motorcycle checks (speed and vehicle check) and to support their communicative efforts in conveying the applicable rules.

1.2.2 Injury crash statistics

In absolute figures, Luxembourg is performing well in terms of road safety, as shown in figure 3. Only 916 injury crashes were reported in 2021, of which 21 had a fatal outcome. In total 1267 victims could be noted in 2021, of which 24 fatalities. A large differentiation between the type of road is present, since only 7.8% of the injury crashes occurred on highways. Further, only three killed motorcyclists were observed in 2021 (4 in 2020) (LU STAT, 2022).

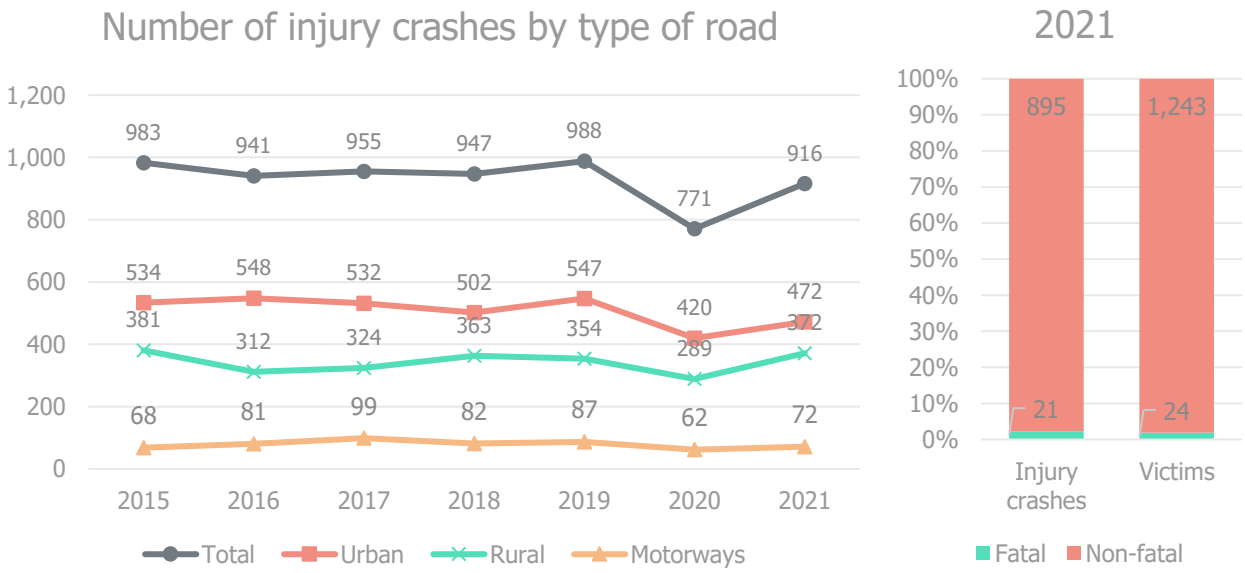

Figure 3: Number of injury crashes by type of road (2015-2021) and fatality and victims for 2021 (LU STAT, 2022)

However, as can be seen in figure 4, when the distribution is made in terms of the number of fatalities per million inhabitants, Luxembourg is performing equal to the European average. In 2020, 42 fatalities per million inhabitants are observed, which is close to countries such as Belgium, Italy, Finland, and France.

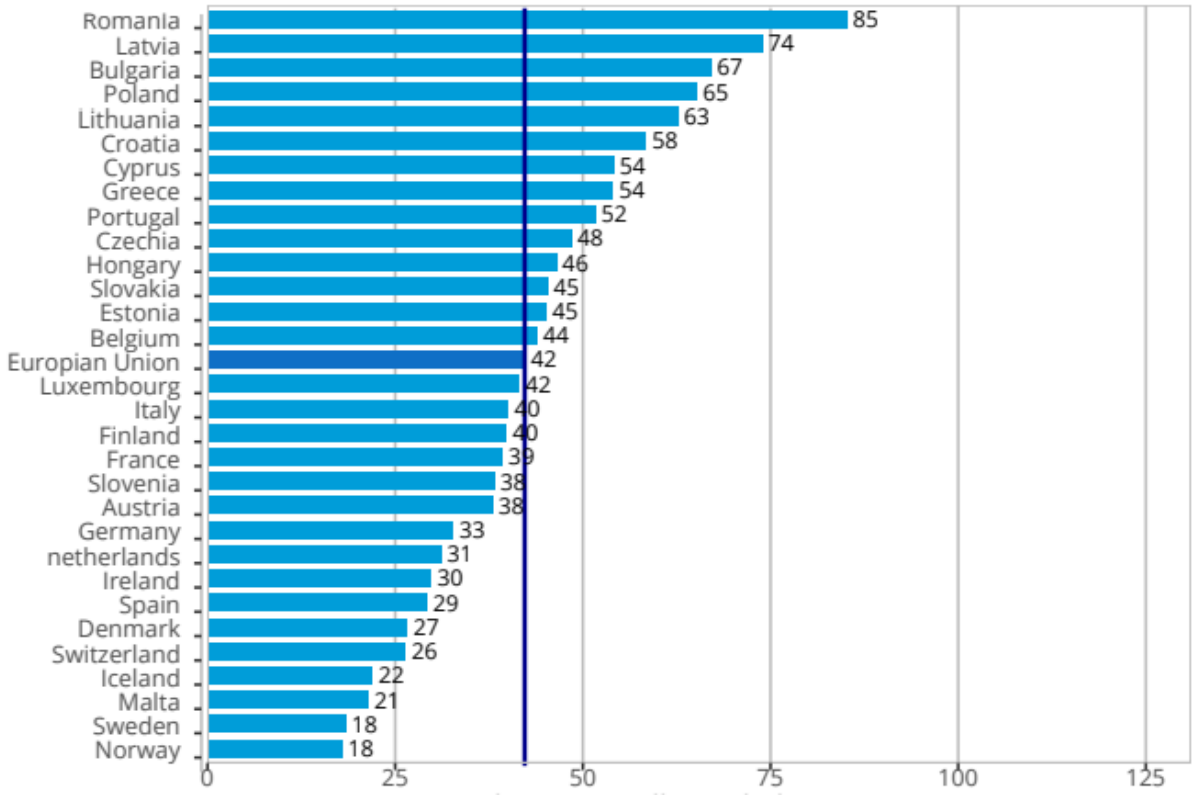

Figure 4: Fatalities per million inhabitants in 2020 (European Commission, 2022)

Giving a closer look to the evolution of mortality in traffic in figure 5, it shows that the relative positions of countries have remained the same over the period 1970-2019. However, the gap between the countries has narrowed over the years. In 1970, Luxembourg had, along with Belgium and France, one of the highest mortality rates. However, rates for Luxembourg and France improved since the start of the millennium bringing these countries in a better position than Belgium in 2019 (Slootmans et al., 2021).

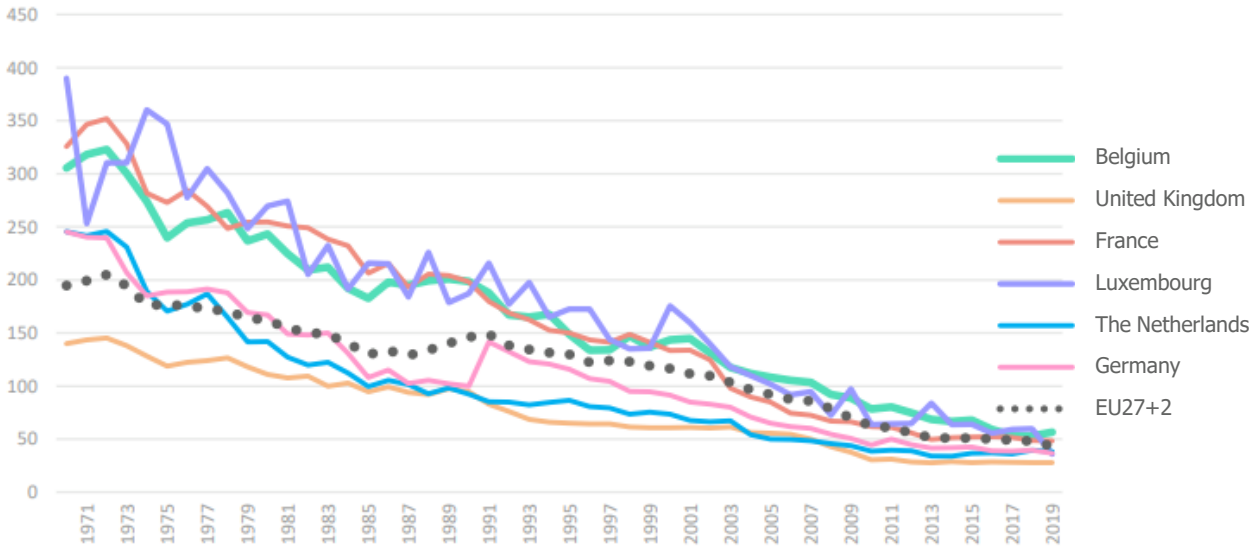

Figure 5: Comparison of the evolution of mortality (number of deaths in traffic per million inhabitants (Slootmans et al., 2021)

Given the low number in fatalities, in absolute figures, in Luxembourg, a slight increase in crashes or fatalities is easily enlarged given the size of the country and its inhabitants. This had to be kept in mind when evaluating results of a policy adaptation.

1.2.3 Congestion

1.2.3.1 Structural congestion

Luxembourg has a dense network of well-maintained roads, bridges and tunnels that is very well-connected to neighbouring countries (i.e. Trier and Cologne (A1), Thionville, Metz and Strasbourg (A3), Brussels (A6) and Saarbrücken (A13)) (The Government of the Grand Dutchy of Luxembourg, 2021). Together with the central location of Luxembourg between Belgium, France, Germany and The Netherlands, large foreign traffic flows are present, additionally to the already extensive car use in the country itself. In fact, statistics put Luxembourg near the top of the list of countries for the number of cars in relation to the total population (The Government of the Grand Dutchy of Luxembourg, 2021).

This high traffic demand asks a lot from the Luxembourgish road network and leads to structural congestion on certain highways. In fact, the A1 and A3 are recurrent moderately to heavily congested, as is the ring road around the capita.

Given the economic plan of Luxembourg, the ministry expects an increase in traffic demand in the coming years. Sustainable transport mode choice becomes an important factor in reducing the increasing congestion levels, while other solutions need to be found to decrease the current congestion levels and reduce the impact on road users.

1.2.3.2 Congestion caused by crashes

In spite of several measures to increase road safety (i.e. ramp metering and regulated speed limits during rush hours), on average, three to five crashes happen on the Luxembourgish' highways *every day*. This causes substantial delay and traffic jams, in addition to the traffic situation that is already dense. In fact, the impact of these traffic jams is sometimes larger in magnitude, when a complete closure of the highway is necessary.

It is argued that, for an injury crash, *ten vehicles* might be needed to resolve the situation:

- Two firefighters: one placed horizontally to protect the immediate surrounding of the crash and one to extinguish possible fires and free occupants from the vehicles.
- One or two ambulances or medical units: to provide medical assistance to the casualties.
- One or two police vehicles: to investigate the crash (causation).
- Three to four vehicles from the road administration: two trucks with dynamic signalisation are parked up-stream, one truck carries the other materials (i.e. beacons, etc.) to guide the traffic past the crash scene more efficiently, and one car with the unit-coordinator.
- Finally the necessary towing vehicle(s), depending on the number of vehicles involved in the crash, to get the crash vehicles out of the way.

All staff involved regularly work together and form a practiced team, in which everyone knows where to put their vehicles in order not to block the access of another (in comparison to other motorised traffic). However, all of them first need to get to the crash site as quickly as possible.

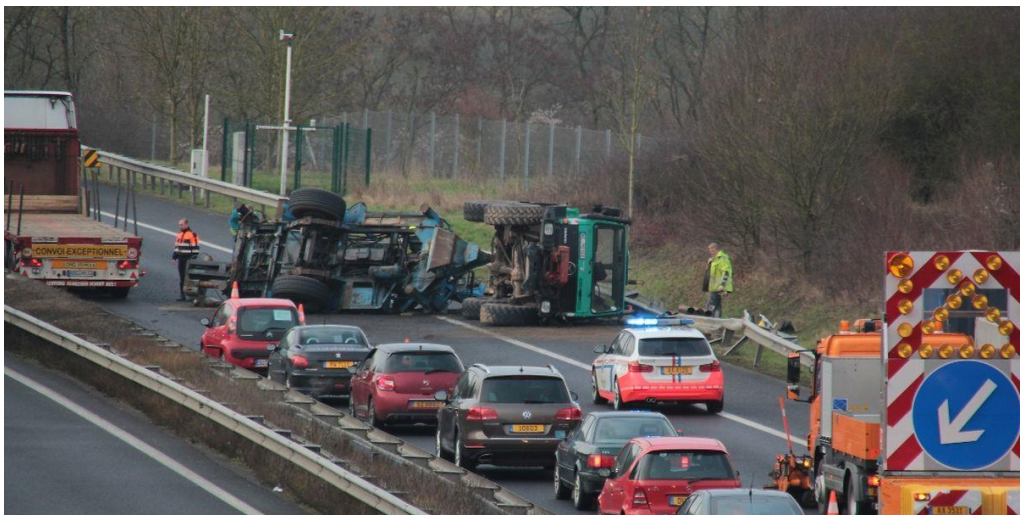

Figure 6: Service vehicles at a crash site

1.2.3.3 Rescue lane

In Luxembourg, like in several neighbouring countries (Germany, Belgium, Austria), car drivers have to make space in a traffic jam for emergency and other service vehicles that need priority access to the scene. This space, that has to be created, is called a rescue lane and must be formed between the two left-most lanes on a highway. Note, that in this report the term *rescue lane does not refer to the hard shoulder on the right (also called breakdown lane)*, even if in some countries (France and partly The Netherlands) it is used by emergency vehicles.

The rescue lane is key to dealing with crashes efficiently. For a crash victim, every minute and every second can make a difference between life or death. Since emergency services must find their way through the traffic jams, allowing emergency vehicles to get to the crash scene quickly is essential to the victim's chance of survival and recovery. Subsequently, the rescue lane is also important for the efficient guidance of traffic around the crash site and getting the traffic back to normal. Not all crashes are equally serious, but will always cause traffic delays. So, the efficiency of the team that resolves the crash situation is also essential for reducing the additional traffic jams to the minimum.

Next to the emergency vehicles, road administration vehicles and tow trucks are also allowed to make use of the rescue lane in order to help clean the crash scene and get traffic moving again. Given their quite large vehicle size, they often acknowledge problems with the rescue lane, as they are particularly dependent on car drivers leaving sufficient space spontaneously. Since these administration vehicles and trucks do not have blue flashing lights or sirens, car drivers tend to disregard them, or do not notice them, and therefore do not move out of the way. In fact, for these large maintenance and towing vehicles, a broad rescue lane that is kept open, even when no rescue vehicle is approaching, makes a significant difference to their response time and time until traffic can start moving again.

Since the rescue lane is so important, country authorities, together with private associations like ACL (Automobile club Luxembourg) and Sécurité Routière ASBL, spent considerable efforts via campaigns to inform car drivers about the rescue lane and to ensure that it is respected by all road users. Examples of these campaigns are show in figure 7.

Figure 7: Luxembourg campaigns to respect of the rescue lane.

As a result, the principle of the rescue lane is generally understood (apart from the improvements that still can be made in favour of road administration vehicles). However, the day to day practice is not always respected.

Rescue lane is not opened spontaneously or closes after a rescue vehicle has passed

This happens routinely. Truck drivers are generally more disciplined than car drivers. Moreover, on the A1 and A13 with many German drivers (where the rescue lane is well established), the lane is kept open spontaneously, while the highways to/from France (A3 and A4) and Belgium (A6) seem to be occupied by drivers who do not keep the lane open. For the rescue services, not forming a rescue lane spontaneously is mainly a problem at complete standstill when there is not enough room for standstill drivers to get out of the way when the services are approaching. On the other hand, in standstill traffic, the lane is usually kept open even after a rescue vehicle has passed.

Drivers or riders use the rescue lane/follow the rescue vehicle

While possible for all drivers, this is typically done by motorcyclists and becomes a problem when the road is completely closed after a crash. In that case, vehicles in the rescue lane tend to become an obstacle since they used the rescue lane up to the crash scene, but then get stuck there. They form an obstacle for the arriving emergency vehicles and are a nuisance for the work of the rescue services (i.e. voyeurs, curious drivers).

2 Benchmark

2.1 Lane filtering in general

The location where motorcyclists filter between lanes (i.e. between the two left most lanes), in neighbouring countries where it is officially allowed (i.e. Belgium, The Netherlands, and France on an experimental level), is the same as the reserved rescue lane in Germany, Luxembourg and Austria. Theoretically, both could be combined, since the rescue lane leaves enough room for motorcyclists to pass safely. However, concerns are raised in relation to this possibility. This section provides a complete overview of the multiple views and opinions surrounding lane filtering.

2.1.1 General arguments in favour of lane filtering

Many arguments advocate in favour of lane filtering. Some arguments tend to be more convincing, such as: avoiding rear-end crashes, mobility benefits, a possibility to set rules to let the already existing behaviour occur safely, and reduced heat exposure. Other arguments are rather a relevant afterthought, such as: less exposure to exhaust gasses, reduced concentration time due to shorter trips, less exposure to cold and wet weather, and less chance on exposure to flying debris out of trucks. In what follows, more information on these arguments is provided.

Vehicles that strand at the rear end of a traffic jam are particularly at risk to suffer a rear-end collision. This is dangerous for all road users. However, for motorcyclists the risk is thought to be higher, because they are smaller and therefore easier overlooked. Even more important, *when* a motorcyclist is hit by another vehicle from the rear, a motorcyclist is at much greater risk of a heavy injury or death, due to the absence of a protective shell, such as cars. By allowing lane filtering, motorcyclists do not have to remain at the tail of the traffic jam, but can filter between cars, thereby lowering the risk on a rear-end collision.

Next, mobility benefits are thought to be achieved when lane filtering would be legally allowed. Motorcyclists take up less space on the road and can filter between vehicles in stalled traffic. Because of this, lost hours, as a result of traffic congestion, are kept to a minimum. Even though lane filtering already occurs today, it is assumed that a legalisation can increase motorcycling interest, and therefore further increase the number of motorcyclists on the road that can pass through traffic, further reducing lost hours in traffic. It is believed that the rule could convince car drivers to switch to a powered-two-wheeler, therefore reducing the number of cars and thus improving traffic flow for all road users. Furthermore, it is also believed that this could aid a better sharing of the road, and therefore increase mutual understanding between road users.

As mentioned, in most countries (admittedly to varying degrees) motorcyclists lane-filter when there is a traffic jam, regardless the legality of the action. It can be assumed that it is safer to put some rules of conduct on this behaviour. Not only could this help avoid a large differentiation on how this behaviour is performed, it could also prevent a grey zone with legal uncertainty. This is why this principle has been applied in the Netherlands (see section 2.2.4). Furthermore, it provides the opportunity for training purposes, since a prohibited behaviour cannot be taught in driving and riding schools.

Moreover, heat is a large problem for motorcyclists who are stuck in traffic during the summer months, which can cause substantial heat stress. This strain can impair the rider's concentration, and therefore endangers road safety. The heat of the engine, which is usually located directly under the rider, rises when the motorcycle is stationary. Engine oil and coolant temperatures of over 90 degrees Celsius are quickly reached in traffic jams. Furthermore, the safety equipment can become very warm in hot weather and especially in congestion, which creates an absence of an airstream that usually cools a motorcyclist. Moreover, motorcyclists cannot easily drink water while they are on the road (except if they are using a hydration pack) and therefore get dehydrated more easily. Allowing lane filtering reduces prolonged exposure to this heat, and avoids the loss of a cooling air stream that cools the riders and his/her machine down.

Additionally, like cyclists, motorcyclists are directly exposed to the emissions of the motor vehicles they share the road with. A traffic jam therefore has a much more severe impact on their pulmonary system, compared to the impact on car-occupants who are protected by an air filtering system. Being able to ride through congestion, can reduce the prolonged higher exposure to these exhaust gasses.

Also, concentration is important for motorcyclists, even more than for car drivers. Keeping exact track of what the car drivers around them are doing is a life-saving necessity, since they are more easily overlooked and less protected in the case of a crash. As a consequence, the duration of a trip – especially on crowded roads – is more taxing to them than to drivers of cars, vans, and trucks. Being able to pass congestion is believed to reduce this travel time, and as a result also concentration time, keeping the rider more "fresh".

Although less of a problem than heat, prolonged exposure to cold and wet weather due to congestion also has a negative effect on road safety by creating a locomotor disability. As a result, hands and feet can become numb and concentration can become impaired, which can be dangerous if an emergency manoeuvre is necessary. While this problem can be countered to some extent with qualitative clothing or heated handlebars and seats, it can be unaffordable for some riders. Being able to the reduce travel time, especially in case of congestion, can lower the risk on these induced effects by cold and wet weather.

Lastly, construction sites and the associated trucks bear a risk to motorcyclists, because they routinely loose debris and small parts of their loads. While this is not necessarily a problem for the maintenance of the road, a motorcyclist riding directly behind the truck can be put at extreme risks by small parts, dirt, etc. flying around behind a truck, even at low speeds. Overtaking is therefore the much safer option, and is mainly relevant in congestion where traffic is still moving forward slowly.

2.1.2 General arguments against lane filtering

As with the arguments in favour of lane filtering, many arguments also exist against. Here, as well, some arguments tend to be more convincing, such as: the belief that behaviour will become more audacious, it will have an impact on the rescue lane, it could make motorcyclists less visible, and liability becomes less clear. Other relevant arguments against lane filtering are less strong, such as: the point of view from car drivers, the feeling of unfairness, and motorcyclists potentially hindering emergency vehicles. In what follows, more information on these arguments is provided.

As raised earlier, it is often acknowledged that lane filtering occurs irrespective of its legality. An important concern for the legalisation lies in the assumption that this behaviour would become more frequent and more audacious. It could be argued that, due to a legalisation, motorcyclists would choose to filter at higher speeds, potentially even faster than the speed limit on the road (e.g. passing through cars driving at 120 km/h).

The largest worry of police, road administration, and rescue services concerns the (legal) presence of motorcyclists in the rescue lane. It is believed that, after all efforts to achieve a good respect of the rescue lane, allowing motorcyclists in the rescue lane would be a huge setback and could undermine the respect of the rescue lane by other drivers (i.e. closing the rescue lane, or worse, following the motorcyclist). To begin, concerns are raised that the rescue lane could be closed by other (disagreeing) drivers when a motorcyclist makes use of the lane or follows the emergency services. Additionally concerns are raised about car drivers following a motorcyclist in the rescue lane. While entering into the rescue lane by car drivers is currently extremely rare, it is feared that this practice would increase, when motorcyclists would be legally allowed to enter the rescue lane.

Next, as motorcycles are relatively small, their visibility is a problem. This is not only a problem with lane filtering, but a problem in general. However, in the rear view mirror, this lack of visibility is even increased, especially in combination with other (larger) vehicles and their headlights (i.e. either the motorcyclist is behind the vehicle and thus invisible, or in front of the vehicle where their silhouette may be difficult to determine, because of low contrast with the vehicle behind them). In the dark, the visibility is even worse. In particular car drivers might not understand that they see a motorcyclist rather than a car with one broken headlight – and consequently not expect a lane filtering event.

Furthermore, if anything happens when lane filtering is forbidden, the liability would be clear: given the illegality of the practice, it is the motorcyclist's responsibility to bear the legal consequences. In fact, (s)he has to be the one that has to make sure that lane filtering occurs safely. However, determining the liability becomes more complicated when this practice is legalised.

Sometimes, the point of view from car drivers is also put forward as an argument against lane filtering. Many drivers do not take motorcyclists into account coming up from behind. In congestion, cars change lanes unexpectedly - often without using an indicator – or drivers get out of the car to stretch their legs. While car drivers are legally obligated to look out when performing a manoeuvre, this could pose additional risk to lane filtering motorcyclists. Furthermore, in all European countries, it is forbidden to overtake other road users on

the right side. Therefore, drivers mainly keep an eye on the space behind them on the left side. As a consequence, checking the righthand mirror is less of a reflex than checking the left one. Motorcyclists coming from the right, as well as other vehicles, can therefore be easily overlooked. To add, in some countries, driving with two vehicles in the same lane next to each other is not allowed. When a motorcyclist filters through the vehicles, this will always be the case. Additionally, car drivers sometimes want to warn for congestion forming ahead through the hazard lights. It is argued that this could create situations that would be dangerous for themselves and for the motorcyclist.

To add, lane filtering can be seen as an antisocial and unfair behaviour performed by motorcyclists from the perspective of car drivers. It is believed that fairness is important in traffic to help mutual understanding, respect, and courtesy. When motorcyclists filter between lanes, they are technically skipping the traffic jam in which other road users are stuck, which can result in this feeling of unfairness. However, one could argue that this benefit is also present for cyclists, public transport, taxi's, and vehicles on car pool lanes.

Lastly, as mentioned in section 1.2.3.3, concerns arise that lane filtering motorcyclists could hinder emergency services in the rescue lane. This especially when a road is closed and motorcyclists start to pile up right at the crash scene. However, motorcyclists are usually fast and manoeuvrable enough to stay out of the way of the approaching emergency vehicles (e.g. by finding a small empty spot between two vehicles to let the emergency vehicle pass). Furthermore, are complete road closures relatively rare and kept to the absolute minimum. Additionally, it is believed that motorcyclists would not form a major problem for the rescue and maintenance services, provided that a code of conduct would be followed (e.g. motorcyclists stay strictly out of the way of all service vehicles approaching – even when the road is closed).

2.1.3 Speed and enforcement

Appropriate speed and enforcement is important to let lane filtering occur safely. Experts' opinions varied mostly on the aspect of speed. Experts from Germany and the Netherlands (including motorcyclists) judge the speed, that they observe with lane filtering motorcyclists in Belgium and France as unsafe. Observers from France, on the other hand (including non-motorcyclists), find the behaviour observed during a test period for lane filtering, grosso modo safe enough, even though compliance with the speed limit in France is described as "improved but still minor".

Nevertheless, when an appropriate speed limit for lane filtering was asked to the experts, most experts hinted towards a 50-60km/h maximum speed for lane filtering and a maximum 10-20km/h speed difference between motorcyclists and other road users. In fact, in France, the maximum speed limit for lane filtering was placed at 50km/h during a testing phase, to be in accordance with a police officer who argued that the speed should be logical. Namely, in France, the maximum speed limit on highways during foggy situations is set at 50km/h, even when a driver cannot see farther than a couple of meters. Therefore, a maximum speed limit of 50km/h was also chosen for lane filtering.

Anyhow, with appropriate speed, enforcement also comes into place. Police from different countries agree that present-day speed control mechanisms do not allow to control separate speed limits for different types of road users. For that reason, in the Netherlands, no maximum speed limit for lane filtering motorcyclists exists (except for a maximum speed difference of 10km/h, which is difficult to enforce). In general the police is against a rule that they cannot enforce. When lane filtering was legalised in the Netherlands, enforcement efforts were focused on "personal enforcement" (i.e. police-motorcyclists who commanded misbehaving motorcyclists as well as car drivers to the road side to explain to them why their behaviour was unsafe).

While personal enforcement and education, performed at the moment of a caught infraction, might be appreciated by those who are taught that way, it can become very expensive to increase the chance of being caught for unsafe behaviour, just for a education purpose. To achieve a broad enforcement coverage, automatisation of enforcement is probably necessary. While such speed enforcement equipment might not be in standard use by the police yet, it should be achievable to automate speed enforcement. Modern smart cameras can differentiate between different road user types and the application of a separate speed limit for lane filtering motorcyclists is well within the range of standard applications for many image-processing systems. Nevertheless, traffic safety must be the basic premise, not increasing the states budget.

It must be kept in mind that a rule that cannot be enforced, can loose its effect. However, not regulating and enforcing the behaviour can also lead to unwanted and unsafe behaviours (with both car drivers and motorcyclists). While some rules cannot be easily enforced, experts indicate that they can be taken into consideration after a crash. This is especially important in determining the liability.

2.1.4 Liability

In countries where lane filtering is forbidden, any crash occurring during lane filtering would be considered as the motorcyclists' responsibility.

In countries where lane filtering is legally allowed, a different situation arises. In these countries, lane filtering is defined as passing, which means that a lane filtering motorcyclist does not conduct a manoeuvre (which would otherwise be considered as overtaking), but simply continues his/her way. Since it is not considered to be a manoeuvre, motorcyclists can not be made responsible in case of a crash. This means that other road users can be held accountable for a crash, with a lane filtering motorcyclists, when they didn't pay attention to motorcyclists filtering between lanes (e.g. check mirrors, signalise a manoeuvre, etc.). In fact, a lane change is considered to be a manoeuvre, obliging road users to give the right of way to vehicles that are already on the road, and signalising their manoeuvre with their indicators.

Important to note, this only applies when the motorcyclist complies to the "playing" rules that are set out for lane filtering. The basic rule can therefore be modified, taking into consideration safe behaviour of the rider as well as the speed of the motorcyclist. This can be the absolute speed of the motorcyclists (i.e. the speed the motorcyclist is riding in relation to the speed limit or maximum allowed lane filtering speed, for example 50km/h) and/or the relative speed (i.e. the speed difference between the motorcyclist and other motorised traffic, for example a speed difference of 30km/h).

2.1.5 Communication and education

As an answer on the question; whether or not a good communication is essential when lane filtering would be legalised, all experts emphasized the need for communication and education to make sure the behaviour can be safely performed. In the case of France, for example, legalisation is thought to be the main reason to be able to regulate the behaviour and let it be performed safely. Information distributed via road side signs, on bridges, flyers, advertisements online, traditional media, events, etc. is important to target the information to riders and drivers to the same extent. An example is provided in figure 8.

Figure 8 Campaigns from France (left) and the Netherlands (right) to make the change in legislation known

Moreover, all experts emphasize the need to make other road users aware to take lane filtering motorcyclists into account and adapt their behaviour accordingly. As an example, in the Netherlands, there was a large campaign "make space for motorcyclists", which not only informed car drivers and motorcyclists that lane filtering is legal but also proposed some "rules of conduct" (the righthand figure of figure 8).

While each point was explained in detail in this campaign in The Netherlands, the main messages were:

- For car drivers
  - Keep an eye on the traffic behind and avoid distracting elements (e.g. phone)
  - Use the middle of the lane and avoid slaloming
  - Check for up-coming motorcyclists before changing lanes and use the indicator
  - Don't open the door! (except in emergencies…)
- For the motorcyclists:
  - Have an adequate speed
  - Be attentive for careless behaviour and distraction (e.g. turned wheels, phone use, foreign drivers, cars moving slowly which can easier manoeuvre compared to stopped cars)
  - Keep distance from other motorcyclists filtering lanes
  - Warn road users behind for a traffic jam and check rear view mirrors for rear-end traffic
  - You are safer between vehicles than at the end of the queue
  - Ride between the two left-most lanes
  - Don't ride on the hard shoulders or other designated lanes / spaces (unless allowed)
  - Avoid using hazard light or mounting additional lights that can cause confusion
  - When congestion resolves go back to normal use of the lanes

Furthermore, this should be included in the curriculum for both motorcyclists and car drivers, since the responsibility of lane filtering should not only lie with the motorcyclist, but also the other road users. These rules of conduct were taught in driving and riding schools in The Netherlands and have also been accepted by the insurances as a guideline when evaluating liability in the case of crashes.

2.2 Lane filtering in other countries

2.2.1 France

Based on the interviews with French experts, originally, lane filtering was tolerated by the police in France and enforcement on the behaviour depended largely on the police officer. In some regions it was more common practice than in others. Since the behaviour was already quite common and enforcement seen to be "unfair", rider organisations wanted to integrate the behaviour in the legislation. It was believed that a legalisation held the opportunity to introduce rules, training, and common understanding between road users. As a result, different actions were organised and some studies performed (Aupetit et al., 2015; Guyot, 2012), which can be seen as a precursor for the larger experimental study drafted in 2016 (cfr. (Beltrami & Hiron, 2021)).

In France, lane filtering was legally allowed as an experiment (cfr. (Beltrami & Hiron, 2021)) in 11 departments in 2016. The selection of these departments was founded based on the departments where lane filtering was rather common practice, even before the start of the experiment. In the other departments lane filtering remained in principle forbidden, but no particular efforts were made to enforce it, except for some random checks. The main aim of this experiment was to provide evidence on the safety or unsafety of allowing lane filtering, and to explore the ability to regulate this widespread practice. A second experiment was launched in 2021 and will continue to 2024. More departments are included in the last version.

The purpose of these two experiments was/is:

- To set standardised national rules for lane filtering
- Improved sharing of the road between all users of target road networks
- Assess the impact of these rules in terms of safety for powered two- and four-wheeled vehicle users
- Teach the rules for legal lane filtering in driving/riding lessons for all motorised vehicles (if the rules become the national standard)

In these experimental departments, the absolute speed limit for the rider to filter between lanes was set at 50 km/h. Results showed that respect of the speed limit by lane filtering motorcyclists was modest from the start of the experiment, but improved throughout the years. From the start of the experiment, the legal speed limit was only respected by 23% of the lane filtering motorcyclists. By the end of the experimental period, this increased to 40%. When including the 5 km/h error margin (allowed by the French law), half of the motorcyclists respected the speed limit at the end of the experiment. Furthermore, the proportion of motorcyclists filtering with high speeds (i.e. 70 km/h or more) significantly dropped (i.e. from 20% in 2015 to 9% at the end of experimental period).

Additionally, observations from the first experiment revealed that the appropriate lane filtering position of the motorcyclist was almost always respected (i.e. in 95% of the cases).

Further, the first experiment showed that a low awareness of the experiment was present with other road users. In fact only 30% to 50% of the drivers were aware of the experiment, while 20% of the drivers believed lane filtering was actually allowed by law. No changes in their reported behaviour were observed over the years. It is believed that this was a result of car drivers that felt very little affected by the experiment. Furthermore, two thirds of the drivers did not adapt their behaviour since they either believed it is the responsibility of the motorcycle riders to change their riding habits, or because they weren't aware of the experiment and rules. While moving aside to block the passage of the motorcyclists happened in some occasions (i.e. in 63% of the cases drivers indicate to never block the passage for motorcyclists), this behaviour didn't drastically change over the experimental period. It is argued that blocking the passage for motorcyclists can be linked to the insufficient knowledge about the practice. Contrary to car drivers, motorcyclists did change their behaviour more often throughout the years.

In general, the study showed that not all lane filtering conditions were respected, but that the behaviour of motorcyclists specifically did improve after legalisation and communication. This illustrates the benefits of regulating the behaviour. Nevertheless, the aspect of speed and communication remain points of attention, given the fact that not all motorcycle riders respected the speed limit, and other road users were lacking awareness on the practice. Either way, in determining the success, it is necessary to be aware that always some riders and drivers will blatantly ignore the rules, regardless the legality of lane filtering.

One of the recommendations of the researchers who conducted experiment 1 is that technical developments are necessary to systematically enforce the speeds of motorcycles. On the other hand, experts also indicate that enforcement based on leaflets in the first months of the introduction (i.e. education instead of immediate fining) can also help to impose appropriate behaviour.

Focussing on the second experiment, legislation was adapted in relation to the 2021 experiment. Here a maximum speed difference between vehicles was added and set to 30 km/h, based on the observation during the 2016 experiment, where the speed difference between motorcyclists and car drivers was found to situate between 20 and 30 km/h. The position of the motorcyclist was also set between the two left-most lanes[1].

As mentioned earlier, the communication of the original experiment was suboptimal. Only 30-50% of the riders and drivers in the experimental areas were aware of the applicable rules. Therefore, the communication was more prominent in the second experiment. This was achieved through press articles, flyers, and in some cases by road signs.

The use of communication in driving and riding schools was also found to be an issue during experiment 1. An important objective of the legalisation of lane filtering is its integration into the curriculum for driver and rider-training. As lane filtering was not allowed before experiment 1, there was no course material available yet at the time of the experiment. Most instructors in the experimental departments that were aware of the experiment, had to find the rules on the internet themselves in order to teach them to their learner drivers and riders. However, for the second experiment, learning and testing materials are provided to schools and test-centres.

To this date, the government of France has not accepted lane filtering as a generally legal practice, although it is still commonly performed. No action has been taken as the results of the crash-analyses in experiment 1 were found to be inconclusive (see section 4.5). For a final decision the results of experiment 2 are awaited.

[1] I. Lane filtering is authorized on highways and dual carriageways separated by a central reservation and equipped with at least two lanes each, where the maximum authorized speed is greater than or equal to 70 km/h, when due to its density, traffic is established there in uninterrupted lines on all lanes other than those reserved, where applicable, for the circulation of certain specific categories of vehicles or users.
II. Traffic between lanes is authorized for any driver whose vehicle is a maximum width of one meter and falls under category L3e or L5e.
III. Traffic between lanes is carried out in compliance with the following conditions:
1° The lateral spacing between vehicles traveling in the two leftmost lanes of a roadway is sufficient;
2° None of the traffic lanes on the roadway is under construction or covered with snow or ice on all or part of its surface;
3° Before driving between lanes, the driver warns the other users of his intention;
4° The speed of vehicles between lanes may not exceed by more than 30 km/h that of vehicles traveling in the two leftmost lanes, within the limit of 50 km/h;
5° It is forbidden for a lane filtering vehicle to overtake another lane filtering vehicle;
6° The driver that lane filters must resume his place in the normal flow of traffic, after warning the other users of his intention, when the vehicles, on at least one of the two lanes, are traveling at a higher speed than his.

Lastly, based on the expert interviews with regards to rescue operations, rescue vehicles in France use the breakdown lane on the very right. Only exceptionally (e.g. if the breakdown lane is blocked or not present), emergency vehicles would use the space that is used for lane filtering (i.e. between the two leftmost lanes). As a result, the main worries from the French government are not focussed on the rescue lane and the compliance towards it. As a result, this does not fall under the scope of the second experiment.

2.2.2 Germany

In Germany lane filtering is forbidden by law (Bund-Länder-Fachausschuss Straßenverkehrs-Ordnung). Although the motorcycle community has asked repeatedly to legalise this practice, neither federal nor regional governments seem to be inclined to restart this discussion. The most important reason for keeping lane filtering illegal is the fear of negative effects on the overall road safety of road users. According to the interviewed experts, these include:

- Problems directly created by motorcyclists
    - The emergency services could be obstructed in the rescue lane by lane filtering motorcyclists that are continuing their way, which cannot be tolerated when every second can count to save human lives.
    - Motorcyclists could accumulate at the very beginning of the accident site. Such an accumulation of motorcyclists would then possibly lead to an obstruction of the emergency services right at the crash scene.
- Problems for motorcyclists created by car drivers
    - Many drivers unexpectedly change lanes in gridlocked traffic because they think they can move faster in the other lane or because they want to get a better overview of the length of the traffic jam.
    - When traffic is stationary, car drivers and passengers often get out of their vehicle, if only to stretch their legs or because they want to investigate the congestion situation.
- General arguments
    - If motorcyclists were allowed to use the rescue lane, imitation effects by four-wheel vehicles could be expected.
    - It is not allowed to ride with two vehicles next to each other in the same lane
    - Overtaking on the right cannot be approved.

The German highway code is considered as very detailed and strict. Furthermore, the situation in other countries is not considered to be relevant by the authorities, because the traffic conditions in different countries are believed not to be comparable. A change of the law is moreover not considered in agreement with their Vision Zero in road traffic. As a result lane filtering is interpreted very strictly against the law.

While no recent official government figures are known on the occurance of lane filtering in Germany, more than 75 percent of German motorcycle riders indicated to ride on highways through the traffic jam according to a survey conducted in 2009 by the 'Institute für Zweiradfahrer' (IFZ). Provided lane filtering was performed safely and not excessive, it used to be largely tolerated by the police. Not only does the 'Institute für Zweiradfahrer' (IFZ) support the legalisation of lane filtering, it has also demonstrated that lane filtering is not among the main causes of motorcycle crashes on German highways (see section 4.4).

The Federal Working Group of Motorcycle riders (BAGMO) has asked the transport ministers of the federal and state governments to open the rescue lane for motorcycles and scooters during traffic jams on highways. Nevertheless, since the introduction of the rescue lane and the up-scaling of its enforcement, lane filtering is tolerated to a much lesser extent than it used to be, resulting in high fines when penalized. Furthermore, critique is raised since lane filtering in the urban context is allowed for cyclists, while still prohibited for motorcyclists.

The authorities have pointed out that in severe congestion (e.g. a full highway closure), the local police command can grant the use of the rescue lane and/or the hard shoulder by hand signal. In addition to motorcyclists, other road users would also be entitled to leave the traffic jam in a timely manner - e.g. elderly people who tire more quickly, families with small children, cardiovascular patients.

2.2.3 Belgium

In Belgium, lane filtering was legalised in 2011. The main opportunities were

- integrating into the highway code what was daily practice already
- providing legal certainty by clearly setting out the rules of lane filtering in the highway code
- confirming that lane filtering is not a manoeuvre (overtaking) but simply passing
- avoiding that the hard-shoulder or breakdown lane would be used
- improving traffic flow by encouraging motorcycling and thus reducing car traffic

Although there were no dedicated data collections or studies performed on lane filtering before the legalisation in 2011, it was generally assumed that no strong impact – neither positive nor negative would follow. The behaviour was already very common practice and was usually tolerated by the police. Except for some articles in the press, no specific communication or education efforts were made. Up to this date the lane filtering rules and practices are not specifically addressed in the training for either riders nor drivers (except for the theory lessons on the Belgian traffic code).

A study was performed in 2016 (Martensen et al., 2016) that made use of motorcycle crashes that happened on the Belgian highways. Only crash data between a motorcyclist and another road user could be used, since specific lane filtering data had never been collected. The study concluded that the legalisation of lane filtering in Belgium did not have a measurable effect on accident occurrence. The accidents that were assumed to be most relevant to lane filtering (i.e. multi-vehicle accidents on highways) represented only a very small part of all motorcycle crashes (2.6%). Comparing the two years before and after the legalisation of lane filtering, these multi-vehicle accidents showed the same slight reduction as single-vehicle motorcycle crashes on highways.

Lane filtering is allowed on Belgian highways only between the two leftmost lanes (on lower category roads, this restriction is not present). The speed difference between the motorcycle rider and other vehicles may not exceed 20 km/h. Furthermore, the absolute speed of the motorcyclist may not exceed 50 km/h, meaning when traffic around the rider exceeds 50 km/h, the rider must re-join the lane. Belgian legislation specifically mentions that lane filtering is not considered as an overtaking manoeuvre.

In terms of enforcement, the police considers the speed restrictions to be practically unenforceable as they lack equipment that makes it possible to measure and compare the speed of the motorcyclist and the speed of other drivers at the same time. In addition, the speed measuring equipment in place cannot be temporarily tuned to motorcyclists driving faster than 50 km/h in congestion on roads with a higher speed limit.

Since October 2020, forming a rescue lane during congestion is obligatory in Belgium. Legislation states that vehicles must make extra space between the two leftmost lanes for emergency vehicles to pass, thereby not allowing to cross the road marking unless necessary. However, to this date this practice is not quite established yet, as indicated by a recent query of the involved emergency personnel showing that most drivers only start to form a rescue lane when they hear or see emergency vehicles approaching, which is considered to be too late. While small emergency vehicles (motorcycles, cars and ambulances) are usually able to use the rescue lane, larger vehicles like fire trucks and towing vehicles still have to use the breakdown lane[2]. A large difference with countries such as Luxembourg and Germany, concerns the fact that the rescue lane was introduced much later in Belgium (i.e. October 2020), years after the legalisation of lane filtering. Lane filtering was already widespread and known by road users in Belgium, taking place in the same position where the rescue lane should be formed. As a result, lane filtering was kept possible during the introduction of the rescue lane. Motorcyclists are not considered to be a problem because their manoeuvrability allows to get out of the way more easily (which is an obligation in case an emergency vehicle approaches).

[2] In Belgium, uncertainty is raised by the interviewed experts whether the position of the rescue lane is ideal: would it not make more sense to move all traffic tot the left, so that more space is created on the breakdown lane.

2.2.4 The Netherlands

Before 1991 it was forbidden for motorcyclists in the Netherlands to filter between lanes on the highway. However, this prohibition was lifted in 1991, as a result from the following main opportunities:

- Preventing motorcyclist from getting stuck at the end of a congested zone, because with their high vulnerability and low conspicuity (due to their size), this was deemed an extremely dangerous place for motorcyclists.
- Putting rules on what started to become a frequent practice in congested traffic.

The original prohibition originated from the law that specified that two motor vehicles were not allowed to use one lane at the same time. In order to make lane filtering legally possible, this specific prohibition had to be removed. It can be noted that, by removing the prohibition to be able to drive with two vehicles in the same lane, in fact, all road users would technically be allowed to filter between lanes. However, due to an additional specification through rules of conduct (see further) lane filtering was limited to motorcycle riders only.

The initiative to legalise lane filtering was launched by the 'Motorplatform', the Dutch consultative body for motorcycle affairs, consisting out of police, motorcycle groups, road administration, government, etc. In contrast to other countries nowadays, the Dutch authorities decided not to put legally enforceable rules on this practice in the traffic code. In particular – there is no absolute speed limit for lane filtering. Instead, it was communicated widely how road users – both car drivers and motorcyclists - should behave in the case of lane filtering. These "rules of conduct"[3] are widely accepted and have also been included into the curriculum for riders and drivers. They serve as a guidance for the insurances and police in determining who is at fault in occurring crashes, along with article 5 in the Dutch traffic code (Wegenverkeerswet 1994), which states: "It is forbidden for any person to behave in such a way that danger can or might be caused on the road, or that traffic on the road can or might be impeded."

New traffic measures seldomly lead to resistance in the Netherlands, as long as people believe it contributes to the greater good. However, a fair amount of individual enforcement efforts were made by the police in the first years of the legalisation. This was done by 'plucking road users out of traffic' who showed dangerous behaviour in relation to lane filtering (both motorcyclists and car drivers). This was not specifically done to fine them, but to explain the rules and the reasons behind the lane filtering procedure.

Traditionally, emergency vehicles used the breakdown lane to get to a crash scene. However, as room is not always available, drivers of emergency vehicles start using the space between the two left-most lanes as well– i.e. the same place that is foreseen for lane filtering. The Motorplatform has now started revising the rules of conduct for motorcyclists in congestion to take appropriate behaviours from motorcyclists into account, in case an emergency vehicle wants to make use of the same space as lane filtering motorcyclists, to cut through congestion.

2.2.5 Austria

In Austria, lane filtering is forbidden on highways. However, there is a legal ambiguity. Since 1989, motorcyclists are allowed to bypass (i.e. filter) cueing traffic at a cross-road, a level crossing, a roadway narrowing, or similar situations, as long as turning vehicles are not hindered based on article 12.5 of the "Straßenverkehrsordnung". Depending on the interpretation of "similar situations", some argue that bypassing traffic (filtering) on highways is also allowed when traffic is at a complete stand still. However, the predominant interpretation remains that lane filtering on highways is not allowed.

In practice, some motorcyclists do filter between lanes on highways. But when they do, they decide to ride between the two right most lanes or between the breakdown lane and the right lane, since the use of the rescue lane by any kind of unauthorised road user is strictly prohibited and prosecuted by high fines (as is in Germany) . Overall, the subject does not raise as much interest in Austria as compared to the other countries that were investigated. It is believed by experts that motorcyclists in Austria tend to avoid the highways overall.

[3] Rules of conduct on lane filtering in the Netherlands: http://motorplatform.nl/over-ons/samenspel-in-de-file/

2.3 Intermediate discussion benchmark

With its high share of road users from the neighbouring countries, Luxembourg would do good to have legislation similar to those of neighbouring countries, to decrease the chance on foreign drivers and riders that would not be aware of different rules. Yet, between lane filtering and respecting a rescue lane in congestion, two contradicting traditions meet in Luxembourg: lane filtering which is routinely conducted by motorcyclists in France, Belgium, and the Netherlands, and the formation of a rescue lane that has top priority in countries like Germany, Austria, and Luxembourg itself. This is believed to lead to a conflict, since both principles make use of the space situated between traffic in the two-leftmost lanes on a highway, together with the assumption that lane filtering is believed to negatively impact the well established rescue lane in Luxembourg. While at the same time, in Belgium, the rescue lane has been mandated as well, the emergency services in the Netherlands and France seem to use the space between the two left-most lanes more often as well. The question how both concepts can be combined (lane filtering and the formation of a rescue lane) is thus not only interesting for Luxembourg.

In principle, the rescue lane leaves room for the motorcyclists to pass, and it is mostly acknowledged that riders would not form a major problem for the passing emergency vehicles. They usually ride as fast as the rescue services and even if they must be bypassed, they are small and manoeuvrable enough to create room quickly. However, a code of conduct would be necessary to ensure that motorcyclists do not hinder service vehicles – even when the road is closed. Nevertheless it has to be kept in mind that complete road closures are a rare occasion.

The main concern however, is not the mere presence of motorcyclists in the rescue lane, but the fear that their (legally accepted) presence in the rescue lane can influence the proper formation by drivers of four-wheel motor vehicles. It should rather be asked whether making an exception for motorcyclists to enter the rescue lane would be accepted by other drivers. In fact, this acceptance could be facilitated by explaining that car drivers are not disadvantaged, because they will have to wait in any case, regardless if they let the motorcyclists pass or not. The experiences from The Netherlands, Belgium and France suggest that a legalisation of lane filtering does not meet major resistance from car drivers, but in none of these countries the formation of a rescue lane was at stake at times of this legalisation. Therefore, as questionnaire is set up in this study, to be able to answer this question and distributed to car drivers in Luxembourg, Belgium, France, and Germany (discussed in section 5 of this report).

Another concern about legalising lane filtering, is the fear for a behaviour that will become more frequent and audacious. It is feared that motorcyclists would ride at even faster speeds through the congested traffic or even between traffic at normal free-flow situations (e.g., passing a car that drives 120 km/h already). However, the speed measurements performed in the experimental study in France during the first lane filtering experiment contradict this fear. The share of speeding motorcyclists was reduced by more than 20% and the share of extreme speeding (70 km/h or more) was halved during the three years in which lane filtering had been legalised. Furthermore, based on expert opinions, a general speed obedience is also estimated to be present in The Netherlands and Belgium (although being it to a lesser extent in Belgium compared to The Netherlands). So, while prejudices might indicate otherwise, objective evidence suggests that the legalisation of lane filtering can help to reduce excessive speeds and other problematic behaviours - among motorcyclists as well as among car drivers. However, specific enforcement and education remains important to stimulate the appropriate behaviour, with attention for risk homeostasis (i.e. too much training can also lead to unwanted behaviours due to an overestimations of personal skills).

3 Traffic flow effects

As mentioned in the introduction of this study, Luxembourg is a country with a very specific traffic situation, consisting of local/national traffic as well as a high proportion of transit traffic. This tends to create heavy congestion on the Luxembourgish highways, especially in the case of a heavy crash. Motorcycles can partially escape this issue as a result of their manoeuvrability in traffic, since they can filter between slowly moving or stand-still vehicles. If motorcyclists wouldn't be allowed to filter between lanes, they would be affected by congestion in the same way as passenger cars and would therefore additionally lengthen the congestion.

By filtering, motorcyclists save time, reduce vehicle lost hours (i.e. time that drivers loose by being stuck in traffic), and as such make motorcycle riding more attractive. This could attribute to a modal shift from passenger cars to motorcycles, which would further reduce the traffic volume and ease congestion. As such, lane filtering is assumed to not only create time savings for motorcycle riders, but all road users. Even though lane filtering already occurs in Luxembourg today (as well as some other countries), it is assumed that a legalisation can further increase the attractiveness of motorcycling, increasing the hypothesised effects.

This study set up an evaluation of the impact of legalising lane filtering on the traffic flow on highways and is a first contribution in the clarification of some of the above mentioned hypothesis. The detailed traffic flow effects report is included in annex III of this study.

3.1 Methodology

To determine traffic flow effects as a result of the introduction of lane filtering, direct and indirect effects are addressed. Direct effects can be considered as the travel time gains for motorcyclists and car users, since motorcyclists will be able to skip the queue, while car drivers experience a shorter queue, resulting in shorter travel times for both. Additionally, the policy change could increase the attractiveness of motorcycle use (and commuting) leading to a shift from other modes to the motorcycle, which are the indirect effects.

Time savings by allowing lane filtering were addressed by means of estimating congestion functions for selected segments on highways in Luxembourg. A congestion function describes the relationship between travel times and traffic volume. In the current situation, motorcycles and passenger cars similarly affect the congestion function. When lane filtering is allowed, motorcycles take less space and reduce the traffic volume in the congestion function. To estimate this relation, existing data on traffic counts and speed measurements on the highways in Luxembourg were used and complemented with figures retrieved through additional literature research. The speed information (if available) allowed for modelling the traffic flow in a very detailed way over time (per five minutes) for over 170 locations on the highway network. Specific focus was laid on two types of bottlenecks on the Luxembourg network, believed as representative for the whole highway network. The first type characterizes heavy congestion patterns observed on the A3, while the second type characterizes moderate congestion patterns observed on the A1. These congestion patterns are assumed representative for the entire highway network. Additionally, information of the vehicle mix (if available) was used to further calibrate the model (i.e. a modal share for motorcycles in Luxembourg of 0.8% was used). If it is not available, Belgian estimates were used, to avoid non-verifiable estimations.

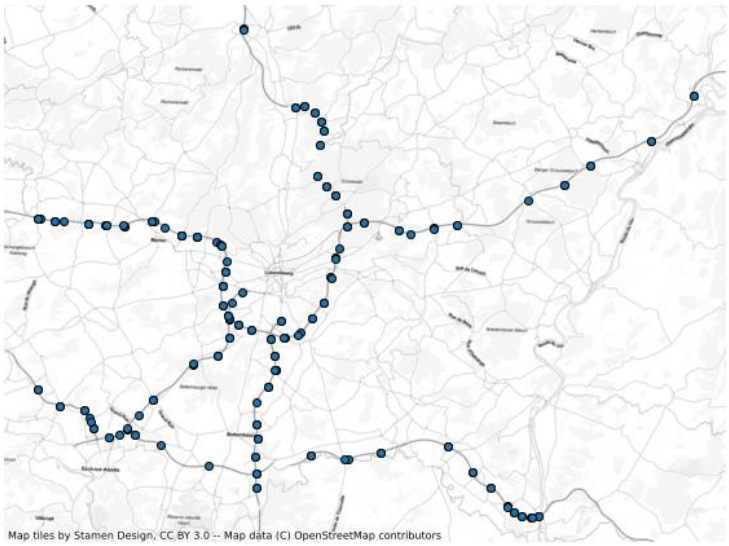

Figure 9: Detector locations on the Luxembourg highway network

Based on this, vehicle hours lost were estimated with and without the policy adaptation. This resulted in an average time gain per vehicle and per kilometre for a specific corridor. The corridors were then extrapolated to the entire Luxembourg highway network. As a result, the total cost of driving a motorcycle and the cost of driving a car could be determined.

Lastly, the total cost of driving a motorcycle was compared to the cost of driving a car. Since motorcycles experience larger time gains, riding a motorcycle becomes more attractive than driving a car for some people. This is assumed to lead to a shift from the car to the motorcycle. In this step, new modal shares of the motorcycles were computed based on cross price elasticities.

Only the interaction between car and motorcycle users were assessed in this study. Furthermore, other delays caused by e.g. a change in the number of accidents and their severity, were not taken into account. A complete and detailed overview of the methodology and analyses can be found in annex III of this report.

3.2 Results

3.2.1 Impact on traffic flow

At free-flow speeds, motorcyclists behave similar to other road users, where no gains are obtained. During congested periods, however, motorcyclists travel between the lanes, therefore decreasing the inflowing traffic and the related travel times. During lane filtering, it was determined that motorcyclists travel 25 km/h faster than the other road users, and that lane filtering cannot occur at speeds above 50 km/h.

When lane filtering is permitted, the travel time of cars and motorcycles decrease. For cars and motorcycles, as long as the travel speed measured at each segment of a corridor is above 30 km/h, the travel time remains unchanged. It is found by evaluating the travel times at the total flow. If the speed measured at one segment drops below 30 km/h, the travel time for cars is found by evaluating the travel time at the car flow. The travel time for motorcyclists corresponds with a speed increase of 25 km/h compared to the actual speed.

By comparing the hours lost (= the experienced travel time minus the travel time at free-flow) with and without introducing lane filtering, an average time gain per vehicle and per kilometre could be obtained. This time gain was calculated during the morning peak hours (7 am to 10 am). It is assumed that the observed patterns and time gains would be similar in the evening peak. All time gains were expected to occur during peak periods, as off-peak periods barely show congestion. This was validated by assessing the time gains on a rarely congested corridor of the A7-highway. A focus is mainly laid on structural congestion and not congestion as a result of a crash.

As a result, the following estimated time gains for corridors with free-flow traffic, medium congestion and high congestion were observed, as shown in table 1.

Table 1: Travel time gain per travelled kilometre for cars and motorcycles in three corridors

	Free-flow	Medium congestion	High congestion
Travel time gain for cars per vehicle km [s/vkm]	0	0.07	0.18
Travel time gain for motorcyclists per vkm [s/vkm]	0	5.27	7.80

To better understand the magnitude of these mobility effects, an average time gain for a morning commute of 20 km was calculated over an average highway section. When lane filtering would be allowed, a motorcyclist could save about 1.8 minutes, while a car saves about 2.1 seconds. These limited gains are due to the relatively low share of places and times with an average speed lower than 30 km/h. However, on a day with heavy congestion with an average tempo lower than 30km/h for the whole trip, motorcyclists would gain 16 minutes for the 20 km trip.

Noteworthy, the average speeds below 30 km/h on a 5-minute aggregate only occur on a regular basis on a few locations. In the available data, only in 1.3% of the timestamps and locations recorded a speed lower than 30 km/h. Considering the times when these reduced speeds occur, for morning, evening, and off-peak periods the percentage is equal to 5.1%, 3.0% and 1.0%, respectively. While these percentages do not consider how many vehicles travelled over the sections, it does show that the condition, usually set to permit lane filtering (flow of 30km/h or less), does not occur very often and that such a policy would therefore not drastically alter the average travel times.

3.2.2 Effects on modal share

As a result of the calculated time gains, the use costs for using motorcycles further decrease, since people positively value this time gain. This, on its turn, leads to more people using this mode of transport (i.e. knock-on effect). In principle, car traffic also experiences small benefits, which in theory could also lead to a modal shift towards cars, and/or a shift to using a highway by drivers that previously avoided them. These effects were, however, assumed to be very small. Therefore, in this study, only the effect of car users shifting to motorcycles was calculated, based on the price elasticity. The costs considered to calculate the impact on the modal share, were:

- Total Cost of Ownership (TCO): Motorcycles have a lower TCO compared to cars
- Time costs: lower costs for motorcycles because of allowing lane filtering (not considering that lane filtering already occurs today)
- Other non-monetary costs: comfort, objective and subjective safety feeling

Since motorcycles are cheaper in purchase and usage costs, one could expect that many people prefer the motorcycle over the car already, directly impacting the modal share. However, this expectation is not confirmed given low motorcycle shares in the vehicle fleet. Apparently, people are deterred by other factors of using the motorcycle, such as their objective and subjective safety, comfort, etc. (i.e. the non-monetary costs). Possibly, commuters perceive that the general cost of a motorcycle is at least equal to the general cost of the car. Otherwise, a larger share of motorcyclists would already be expected nowadays. It is therefore assumed that the modal share effects, based on cost calculations, are largely explained by the decreased travel times, due to allowing to lane filter.

Based on this information, it is calculated that the modal share of motorcycles would increase from 0.8% (initially) to 1.3% due to the policy change.

Following these new modal shares, a new estimation of the effects of the legalisation of lane filtering can be made. This is done by changing the current modal share of cars and motorcycles to the newly calculated one. These effects are shown in table 2. As visible, the gains for motorcycles remain unchanged, as it is assumed that the modal shift will not alter the conditions when lane filtering would be allowed (i.e. the speed still has to drop below 30 km/h at the same locations and for the same duration as it does today). The gains for car users do increase because the reduction in the number of cars decreases the travel time more than linearly.

Table 2: Travel time gains per travelled kilometre starting from the new modal share

	Free-flow	Medium congestion	High congestion
Travel time gain for cars per vkm [s/vkm]	0	0.12 (+71%)	0.31 (+72%)
Travel time gain for motorcyclists per vkm [s/vkm]	0	5.27 (+0%)	7.80 (+0%)

3.2.3 Intermediate discussion traffic flow effects

When all effects are taken into consideration (i.e. travel time gains for motorcycle riders and car drivers after the knock-on effect), the effects of the legalisation of lane filtering are present, yet, marginal. This can be concluded based on the travel time gains generalised over the whole network (i.e. 1.8 minutes for motorcycles, and 2.1sec for cars when the knock-on effect is ignored for a trip of 20km on the average Luxembourgish highway network), as well as the monetary yearly gains displayed in table 3. The largest benefits are estimated for motorcyclists in specific situations where heavy congestion would be present for a full 20km trip (i.e. 16 minutes time savings). However, based on the network data, these situations are rather scarce.

Table 3: Travel time gain converted in euros for cars, motorcycles and trucks per travelled kilometre and yearly effect

	Monetary gain per pkm in peak hours [€/pkm]	Monetary gain per year [€/year][4]
Car	0.0011	685 541
Motorcycle	0.0345	268 975
Truck	0.0029	126 815
Total	-	**1 081 332**

[4] Obtained by multiplying the vehicle kilometres during peak hours for one day by 250, to account for weekends and public holidays.

However, it is important to acknowledge that the estimations (based on assumptions), that had to be made for this research, can influence (positively or negatively) the above mentioned results.

Firstly, the initial modal share of motorcycles for Luxembourg is estimated based on Belgian figures, as there is no better data available. The benefits of the policy are influenced by this initial modal share. If the true modal share is higher than the assumed 0.8%, economic effects will be higher. With more initial motorcyclists, the gain per travelled kilometre remains unchanged, but more motorcyclists experience the gain. To illustrate, if the initial modal share equals 2%, a monetary gain of €2,015,058 is achieved (compared to €1,081,332 with an initial modal share of 0.8%). Furthermore, this would constitute a new modal share for motorcycles of 2.5%. The time gains for a car user in this case almost double compared to the previous results (0.22 s/pkm for medium congestion and 0.57 s/pkm for high congestion). The time gains for a motorcyclist remain constant. The effect can thus be larger if higher motorcycle shares are observed.

Secondly, the study assumes that the total travelled distance remains unchanged due to the policy change (i.e. new motorcyclists were previously car users travelling the same distance). However, the time gains can also attract new motorcyclists who were previously using other modes of transport, were not travelling at all, or were car users on the lower category road network. With a low number of added motorcyclists, the effects will be similar as to what was described earlier. But, when many motorcyclists were to be added, which is not expected to happen solely due to this policy, traffic will break down more often and congestion will increase. Mildly congested locations, where lane filtering is not permitted, can become heavily congested, creating more delays for all road users. This violates the assumption that traffic breaks down at the same locations and at the same times with and without the policy, which can further influence the calculated effects in the benefit of lane filtering.

Moreover, the traffic state in 2019 was used in this modelling, while a significant increase in traffic is expected due to economic developments. This might lead to a further increase in congestion, and consequently added benefits of lane filtering.

Next, the study averages and extrapolates the effects over the entire network. By doing so, the benefits are evenly distributed over all motorcyclists. However, it is assumed that this is a simplification of the benefits that can be achieved. For example, while motorcyclists on less congested sections rarely experience any benefits, motorcyclists who often travel along the worst sections of the A3, could experience much higher reductions in travel time (50% and more) than the reported average time gain. In that case, if most of the lane filtering is performed on these worst sections on the A3, and nearly never on other sections, the gains are expected to be much higher.

By contrast, it has to be kept in mind that the monetary and travel time gains can be partly compensated when the reduction in travel times for car users attracts new car users (i.e. latent demand). This can in turn lead again to an increase in the travel times. These effects are hard to estimate, and are expected to be relatively small due to the limited time gains for car users, but cannot be ruled out.

Other policy changes or investments, such as infrastructure projects and incentives to change modes to e.g. cycling were also not taken into account, which might lead to decreases in congestion.

Additionally, by using data on the current traffic patterns, it is assumed that lane filtering is absent in Luxembourg. However, lane filtering is already quite common among current motorcycle riders. This would mean that the to be measured effects could already be present in the data. It can thus be possible that the study may overestimate the benefits.

Also, the study assumes that the selected highways, the A1 and A3, are sufficiently representable for the congestion patterns in Luxembourg. Bottlenecks at other locations, such as on the ring road around Luxembourg City or on the also heavily congested A6, might show different congestion functions, resulting in different time gains. To account for these differences, more complex models, namely a dynamic traffic model, would be required.

Lastly, the study did not take a change in accident risk into account. On the one hand, lane filtering may result in more motorcyclists and an additional crash risk, leading to occasionally more congestion. On the other hand, a good legislative framework could choose to only allow lane changing at low speeds, since a lower speed is found to lead to a lower likelihood of severe crashes (Aarts & van Schagen, 2006; Martensen & Daniels, 2020; Van den Berghe & Pelssers, 2020). Hence, little traffic safety implications are expected. These effects will be determined in the next section.

4 Crash risk

This chapter focusses on crash risk related to lane filtering. Firstly, a concise insight is given on the expected theoretical risk of lane filtering. Secondly, an update of the study from Martensen and colleagues (2016) is performed with recent crash data looking at the number of highway motorcycle crashes in Belgium before and after legalisation. This is done since the situation in Belgium is estimated to be a good predictor for Luxembourg, given the fact that lane filtering was also frequently performed prior to the legalisation. Additionally, an extra modelling is ran on the number of motorcycle related highway crashes. Thirdly, two concise studies, reporting on the type of crashes occurring with motorcyclists on highways collected through police reports, are discussed. Lastly, important findings from the study by Beltrami and Hiron (2021) are discussed, which performed an experimental evaluation of the permission of lane filtering in France. Here, specific focus is laid on the effect on the number of road crashes in France after the experimental legalisation.

4.1 Theoretical risk

Generally, it is assumed that injury risk in lane filtering crashes is rather low. While mass differences between road users cannot be ignored, it is after all the speed that plays an important factor in the impact severity.

In lane filtering, both vehicles travel (if one of both isn't stationary) in the same direction. Countries that allow lane filtering apply a relative speed limit to other vehicles, ranging from 10km/h and 20km/h (the Netherlands and Belgium respectively) to 30 km/h (experimental condition in France). As long as speed differences are kept to a minimum, the impact force will be reduced. This is a result of physics, in which speed in different directions, and their resulted forces in case of a collision, must be added to each other. Vehicles that crash frontally into each other have the maximal relative speed and largest force possible.

From this perspective it is not surprising that lane filtering is not found to be a frequent cause in fatal crashes (Beltrami & Hiron, 2021; IFZ, 2013; Vandenbulcke-P, 2021). However, also the aspect of how often injury crashes occur, due to this practice, is relevant to determine. Though, these are often not coded as a cause of injury crashes, hence evidence for or against the increase of the crash risk remains nevertheless scarce.

4.2 Development of motorcycle crashes on highways in Belgium

This section considers the development of motorcycle crashes on Belgian highways, to determine the impact of the legalisation of lane filtering since its introduction in 2011. Focus is laid on the differential development of multi-vehicle and single-vehicle crashes. This is done, since crashes that involve lane filtering are assumed to happen between a motorcycle and another motorised vehicle (i.e. multi-vehicle crash). It is assumed to be unlikely that a motorcyclist would fall or crash by him or herself, without the cause of another road user (i.e. single-vehicle crash) as a result of lane filtering. To illustrate, figure 10, gives a first overview of the development of these crashes on Belgian highways between 2005 and 2019. The years 2020 and 2021 were not included given the strong influence by the pandemic situation.

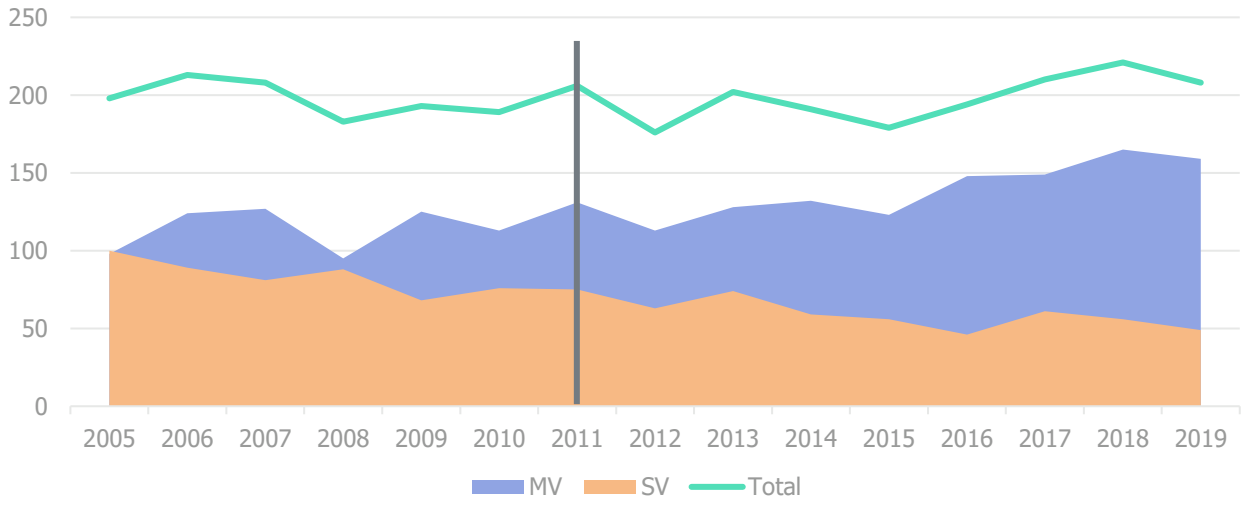

Figure 10 Multi- (MV) and Single-Vehicle (SV) crashes involving motorcycles on Belgian Highways

Figure 10 shows that the total number of crashes involving motorcycles has remained more or less constant over the period 2005-2019. However, the share of single-vehicle and multi-vehicle crashes has changed strongly. While the number of single-vehicle crashes reduce in a more or less continuous way, multi-vehicle crashes steadily increase, after a small dip that seems to be present around 2011 (i.e. the year of the legalisation). In particular the number of multi-vehicle crashes rises strongly since 2016. At first glance, it seems therefore possible that the increase over the years could be a direct result of legalising lane filtering. However, evenly likely, is the possibility that growing congestion influences the proportion of crashes, making single-vehicle crashes less likely and multi-vehicle crashes more likely.

In order to accurately determine the impact of the legalisation of lane filtering on multi- and single-vehicle motorcycle highway crashes, a Prophet model was built. Prophet is a procedure for forecasting time series data based on an additive model where non-linear trends are fit with yearly, weekly, and daily seasonality, plus holiday effects. Time series are a set of observations for a variable at different times and are used to predict future values based on the previous observed value. Time series forecasting and analysis allows to check for an effect of the independent variables on dependent variables, while also predicting/forecasting for the future. It works best with time series that have strong seasonal effects and several seasons of historical data. It is robust to missing data and shifts in trends, and typically handles outliers well. Prophet allows to automatically decompose time series into components such as trend and seasonality.

Prophet includes a generalized method for adding any additional regressor, both binary and continuous. This allows to determine the effect of additional factors/regressors such as temperature, introducing the legalisation of lane filtering, the COVID-19 effect, etc. on the number of multi-vehicle motorcycle crashes. To model seasonality uncertainty and to calculate their significancy, Prophet needs to use an MCMC method (Markov Chain Monte Carlo). A Markov chain is a model that describes a sequence of events, with the probability of each event depending upon the state in the previous event. Prophet models seasonal uncertainty with this chained sequence and uses the Monte Carlo method to repeat the sequence many times. When it is used, a credible interval for each coefficient is returned. This helps to identify whether each factor/regressor is statistically significant.

Prophet has been proven in the past to provide a good fit for the estimation of the number of injured persons for motorcycle crashes in Belgium (occurring on all types of roads), and the total number of crashes on all Belgian roads, using data from 2005 to 2021 (Bas & Martensen, 2022).

The model was able to capture the effect of external factors such as weather conditions, the COVID-19 pandemic (which either significantly increases or decreases the number of crashes), while providing a good fit for the data (i.e. R^2 of 0.60 within MV-crashes, meaning that 60% of the variability observed in the time series can be explained by the Facebook Prophet model). Data on motorcycle crashes was received from Statbel (i.e. the Belgian Statistical Office) and was tailored to the needs of the model, providing information on the number of single- and multi-vehicle crashes on Belgian highways from 2005 to 2021. Data until 2020 was used to build the model, while making predictions for 2021 (otherwise, as a result of the COVID crisis, the fit would be impacted). A confidence interval of 90% (i.e. marginal significance) was chosen, in order to increase the likelihood of finding a statistical effect.

In total, 4 models were built based on multi-vehicle (MV) and single-vehicle (SV) crashes, with a focus on a general monthly basis and peak-hours (a higher likelihood on lane filtering crashes was expected during peak hours, when lane filtering is expected to be performed the most). Results are shown in table 4 and

table 5.

Table 4: Model regressor results for MV-crashes

Regressor	MV monthly			MV monthly (focus on peak hours)		
	Coef	Coef lower	Coef upper	Coef	Coef lower	Coef upper
Temperature	0.059727	0.034825	0.086357	0.057022	0.023345	0.093705
Rain	-0.039458	-0.091026	0.011725	-0.006990	-0.080085	0.058804
Snow	-0.273038	-0.758869	0.195390	-0.415434	-1.049853	0.203588
Vehicle registrations	0.038863	-0.068360	0.137967	0.087135	-0.048336	0.228803
Lane filtering	0.140868	-0.023336	0.336459	0.227701	-0.017880	0.526817
COVID-19 restrictions	-0.010268	-0.013940	-0.006646	-0.010556	-0.016445	-0.005095

Table 5: Model regressor results for SV-crashes

Regressor	SV monthly			SV monthly (focus on peak hours)		
	Coef	Coef lower	Coef upper	Coef	Coef lower	Coef upper
Temperature	0.028461	-0.006043	0.060482	0.021706	-0.039567	0.080135
Rain	-0.057032	-0.128832	0.015038	0.004478	-0.140757	0.141430
Snow	-0.281229	-0.878934	0.323697	-0.839240	-2.025209	0.232480
Vehicle registrations	-0.031212	-0.161986	0.097750	-0.081606	-0.341038	0.154227
Lane filtering	0.053181	-0.121833	0.267844	0.261347	-0.077172	0.725661
COVID-19 restrictions	-0.002794	-0.009485	0.004571	-0.009029	-0.022121	0.004714

As observed in figure 10, MV-crashes were found to show an increasing trend, while SV-crashes were found to show a decreasing trend. MV-crashes were found to be at their highest in September and at their lowest during July, compared to other months during the year SV-crashes show a peak in June and a second peak in September.

The 'coef' columns (i.e. coefficient) in table 4 and

table 5 represent the expected impact on motorcycle highway crashes with a unit of increase in the regressor. For example, the coefficient for temperature is 0.06 in MV-crashes monthly (table 4), indicating that for every degree increase compared to the base value (around 11°C in this case), the expected effect on MV crashes would be a 6% increase. The coefficient of lane filtering, on the other hand, tells that with an introduction of lane filtering, the MV accidents will be 14% higher compared to the period without lane filtering. As for the coefficient 'COVID-19 restrictions', higher COVID-19 restrictions in Belgium pair with a decrease in MV-crashes (i.e. 1% increase for each unit increase in the regulations).

To determine the statistical significance of a coefficient, the columns for 'coef_lower' and 'coef_upper' must be considered. They indicate the lower and upper bounds of the 90% confidence interval around the coefficient. A value can be considered as statistically significant when the coefficient situates itself within the coefficient interval, and the value zero falls outside the coefficient interval (e.g. the coefficient for rain falls between the lower and upper bound of the interval, however, so does the value zero, therefore not significant).

Taking these intervals into account, it can be stated that only the coefficients 'temperature' and 'COVID-19 restrictions' are statistically significant at a 90% confidence level for MV-crashes. For single-vehicle crashes, no coefficient was found to be statistically significant at a 90% confidence level.

Based on these data, lane filtering was found not to have a statistically significant impact on the observed increase of MV-crashes or decrease in SV-crashes. This means that, even though MV-crashes increased after the legalisation of lane filtering, this did not seem to be the determining factor for the increase.

In summary, based on these analyses multi-vehicle crashes show an increasing trend in time, while single-vehicle crashes show a diminishing trend. However, this trend effect was not found to be influenced by lane filtering. It must be stated however, that contrary to motorcycle crashes, the number of crashes with other road users has been reduced over the same period considered. A more or less constant number of motorcycle highway crashes (SV and MV crashes combined) is in itself a problem. To determine this cause, further research would be advised.

4.3 Fatal motorcyclist crashes on highways in Belgium

Studies on highway crashes with motorcyclists in Luxembourg couldn't be identified. Therefore, studies on the topic were sought in Belgium where lane filtering was already legally allowed. As a result, a report from the Belgian federal police was retrieved. The report studied all police reports collected during the period 2015-2021 on fatal highway crashes involving motorcyclists, in the regional provinces of Antwerp, East-Flanders, and Flemish-Brabant in Belgium. The selection of these provinces was based on an increasing number of motorcycle crashes in the province, compared to other provinces, together with a higher likelihood on congestion typical to these provinces (Vandenbulcke-P, 2021).

As a result, 21 crashes in which a motorcyclist died could be identified. Out of these crashes, one crash was found in which lane filtering was performed. Additionally, another crash was found where a motorcyclist was hit at the end of a traffic jam, ending up being crushed between two vehicles. In this latter crash, lane filtering, if performed, could have saved the motorcyclist's life.

The small number of cases do not allow a quantitative conclusion of possible negative effects linked to lane filtering. Since only one police report could be directly linked to lane filtering, it seems that lane filtering is not a dominant cause for the very severe crashes investigated in this study. In fact, the study highlights a neutral, or even positive effect on road safety by allowing lane filtering, since a crash was found where lane filtering would have saved the motorcyclist from dying.

This is in accordance with the assumption, as mentioned in the theoretical risk estimation, that lane filtering is not expected to exert a negative effect on fatal crashes.

4.4 Lane filtering crashes in Nord-Rhein Westfalen

The Institut für Zweiradsicherheit (IFZ) in Germany reports crash figures from the region Nord-Rhein Westfalen (NRW) up to the year 2000 (IFZ, 2013). In total 5,936 crashes on highways were reported in NRW, of which 234 crashes involved a motorcyclist. Out of these 234 motorcycle crashes on highways in NRW, 22 crashes could be identified as a conflict in congestion. They reported, based on a detailed analysis from the police, that no crashes occurred in the rescue lane, but that these crashes could be classified as classic rear-end collisions, accidents while driving off, etc. Based on this information IFZ concluded that no potential danger for lane filtering could be identified in NRW.

While these figures are outdated, and challenging to verify, the findings seem to be coherent with the Belgian crash reports mentioned in section 4.3, and the modelling results in section 4.2. Lane filtering seems to have little to no impact on motorcycle crashes on highways.

4.5 Crashes in the PTW lane filtering experiment in France

As mentioned in section 2.2.1 of this report, an evaluation of the lane filtering experiment had been performed in France by Beltrami & Hiron (2021). For this evaluation, five experimental departments were selected in France:

- Ile-de-France
- Bouches-du-Rhône
- Gironde
- Rhône
- Haute-Garonne (control site)

Data was collected before and during the experiment, on which a before/after analysis was performed, to determine the impact of legalising lane filtering. Firstly, a comparison was made between general accident rates collected before (2012-2014) and during the experiment (2016-2018), Secondly, a comparison was made on attitudes, behaviours, knowledge and 4500 crashes involving Powered-Two-Wheelers (PTWs) between the base condition in which lane filtering was illegal (i.e. the year 2015) and the experimental condition where lane filtering was legalised (i.e. 2016-2018) Crash rates for each department were monitored and compared to the control site where lane filtering was not legally allowed (i.e. Haute-Garonne).

The results of the study showed that, across the whole of France, the general crash rate for PTWs slightly decreased between 2014 and 2018. This was also visible within the experimental departments, where the general crash rates were also found to decrease, except for Rhône and Haute-Garonne (control site), where the crash rates remained constant. This decrease was primarily attributed by the authors to the reduction in the number of scooter and moped crashes.

Further analysis of the specific crash rates, on the specific road networks where lane filtering was experimentally legally allowed, revealed that an increase in crashes was observed (except for the department Rhône), for the network where lane filtering was allowed. When the ratio was calculated between crashes on the experimental lane filtering network, with the total number of crashes per department, an increase was found for the experimental departments, especially in Gironde, except for the department Rhône. An increase was mainly found in the year 2016 (start of the experiment), after which the number of accidents remained stable (Beltrami & Hiron, 2021).

While these results seem to indicate a negative effect of lane filtering, the study shows some shortcomings, that have to be mentioned in our view, that have a direct impact on these findings.

- Firstly, the study only took five departments into account for the whole of France, even though France has 101 departments in total. Of these five departments only one department was chosen as a control department, which can be considered as too few. In fact, in this control department lane filtering was still a common practice, even though kept illegal. This reduces the comparative power and reliability to make a claim for the whole of France.
- Secondly, the increase in motorcycle crashes over the study period in some experimental departments did not consider the increased traffic during that same period. The authors only calculated the number of crashes on lane filtering sections over the total number of crashes that occurred in the department, without controlling for the number of vehicle kilometres travelled (i.e. exposure). This makes it difficult to make direct comparisons, as higher exposure itself already correlates to an increase in crashes (Hakkert & Braimaister, 2002).
- Thirdly, the large increase in PTW crashes in the experimental departments was highly influenced by an increase in lane filtering crashes in Gironde. Here, the authors highlight that traffic volumes increased drastically throughout the experiment, which led to an increase in congestion, and much more occurrences of lane filtering. Therefore a comparison with the base condition is difficult to make since exposure increased drastically which has a direct influence on crash occurrence. Data was not corrected for this.
- Fourthly, the authors of the study mention that data was not robust enough to make claims based on the crash figures, without elaborating on the exact reason for this lack of robustness..
- Lastly, the study calculated a ratio of crashes that occurred on the lane filtering sections relative to the total number of crashes in that department. While an increase in motorcycle crashes could be observed on the experimental road sections, a decrease in the general crash rate was observed that was largely induced by a decrease in moped and scooter crashes. However, mopeds and scooters (<50cc) are not allowed on the experimental sections. Therefore, a comparison with motorcycle crashes only would have been more adequate to determine the exact ratio.

The study found, based on the sample of 4500 PTW crashes observed between 2015 and 2018, 1650 light crashes, 161 serious crashes, and 16 fatal crashes in which PTW riders were practising lane filtering. Crash causes were found to be largely attributable to other road users changing lanes without signalling, as well as inappropriate speed and dangerous overtaking by motorcyclists. Among the 16 fatal PTW crashes, none were riding in compliance with the rules of lane filtering that were set in terms of speed and positioning. These crashes can therefore not only be attributed to the experiment taking place.

Based on the previous it can be argued that the study of Beltrami and Hiron (2021) was inconclusive. While some accidents seem to increase, no conclusive evidence was provided that could be directly related to lane filtering.

4.6 Intermediate discussion

There seems to be no conclusive evidence, based on crash statistics, that lane filtering in itself increases the risk on motorcycle crashes on highways. This can be concluded based on a thorough modelling of motorcycle highway crashes. Also previously performed studies on motorcycle highway crashes do not provide the necessary evidence on an increased risk of crashes as a result of legalising lane filtering.

While the impact of lane filtering on an increase of motorcycling was found to be marginal, based on the modelling study, other facilitating factors (e.g. allowing motorcycles on bus lanes, reducing taxation, lower parking costs, etc.) can also increase the popularity of motorcycling, thereby increasing exposure, which can result in an increase in the number of crashes if no further traffic safety actions are taken. While this doesn't say anything about the risk of lane filtering, and its legalisation effects, it does highlight possible consequences when motorcycling is made more attractive in general.

5 Lane filtering acceptance and spill-over effects

A key part of this study is focussed on better understanding the attitudes and behaviours of drivers in relation to the acceptance of lane filtering. To help understand these attitudes, the concept of the rescue lane had to be incorporated as well. This had to be done since effects on the rescue lane were hypothesised to occur as a spill-over effect from allowing lane filtering (as discussed in chapter 2, a particularly large concern in Luxembourg). In order to better understand this, a quantitative design making use of a questionnaire was distributed through car drivers in Luxembourg and the neighbouring regions.

5.1 Methodology

Given the nature of Luxembourg as a transit country, attitudes and behaviours had to be targeted in relation to lane filtering and the rescue lane, from the perspective of different surrounding countries (i.e. Germany, France, Belgium, and Luxembourg). It was suspected that visits to Luxembourg are higher for the regions/bundesländer situated closest to Luxembourg. therefore, focus was laid on specific regions in Germany (i.e. Rheinland-Pfalz and Saarland) and France (Grand-Est), and not the whole country. For Belgium and Luxembourg data was analysed on a country level. Based on information received through the panel bureau, possible sample sizes were estimated and data was collected nationally or regionally representative. As a result, different sample sizes were collected for each country. Additionally, a weighing factor was applied to account for possible deviations in national representativity based on age, gender (interlocked), and educational level (not-interlocked).

Eligibility criteria were based on permanent driver's license possession, driving in Luxembourg at least once or twice ever, and car/motorcycle/truck or bus use. Motorcyclists were identified in the beginning of the questionnaire, but not excluded, in order to be able to distinguish differing opinions between motorcycle riders and car drivers in the sample). Questions were formulated, taking into account the country of residence, or specifically tailored to Luxembourg. The full questionnaire can be found in annex I of the research report.

The questionnaire took the following aspects into account:

- demographic information (gender, age, nationality, living province/region, frequency of driving in Luxembourg, transport mode use information).
- General knowledge, attitudes, and behaviours in relation to the rescue lane (not country specific).
- Stated behaviours on the respect of the rescue lane in Luxembourg.
- General knowledge, attitudes, and behaviours in relation to lane filtering (country specific).

Stated behaviours concerning the respect of the rescue lane in Luxembourg were questioned through realistic use cases. They focussed on the formation of a rescue lane, with and without the presence of a lane filtering motorcyclist, and provided contextual information (in the form of text), a picture[5], and specific items of interest. An example of such a case is provided in table 6.

In total six cases were formulated, each consisting out of three items of interest. Out of the six cases, two cases focussed on going towards the rescue lane to see what is happening, two cases focussed on the urge of wanting to use the rescue lane as a driver, and the two final cases focussed on blocking the access of the rescue lane (for unauthorised drivers/riders). Each respondent was provided with each of the six cases, never receiving the same case twice with and without a motorcyclist present. In order to exclude order effects, the six cases were counterbalanced between participants. Furthermore, each respondent received for each of the three conditions (moving to the rescue lane, urge to use the rescue lane, and blocking the rescue lane) one case with a motorcyclist, and one case without. This led to the counter balancing strategy as shown in table 7.

[5] Pictures were manipulated using Adobe Photoshop

Table 6: Example of a drafted stated behaviour question on making use of the rescue lane

General question	
Now, imagine yourself that you are driving a car on the right lane on the highway in Luxembourg. Suddenly you get caught up in a traffic jam. The exit you want to take is only 500m away, but there is no room to pass vehicles on the right. A rescue lane is formed and after waiting for 20 minutes, not a single car has moved for even 1 metre.	
With lane filtering motorcyclist	**Without lane filtering motorcyclist**
	
Items of interest (equal whether or not a motorcyclist is shown)	
What would you do? – Stay where I am right now at the far right in the rescue lane even if it takes another 20min. – Move to the left to see if I can already spot my exit and understand what is going on. – Make use of the rescue lane since it is only a very short distance to my next exit. Answers could be given on the following answering scale: Not likely at all – Not likely – Likely – very likely – I don't know	

Table 7: Counter balancing strategy in the questionnaire

	Person A		Person B	
	Without rider(s)	With rider(s)	Without rider(s)	With rider(s)
Case 1 (moving to middle)	X			X
Case 2 (moving to middle)		X	X	
Case 3 (using rescue lane)		X	X	
Case 4 (using rescue lane)	X			X
Case 5 (blocking rescue lane)	X			X
Case 6 (blocking rescue lane)		X	X	

5.2 Sample background information

In total 3,100 respondents who filled in the questionnaire were collected in four countries: Belgium (1,000), France (600), Germany (750), and Luxembourg (750). An overview of the sample is provided in table 8.

Table 8: Sample descriptives

Belgium		Luxembourg	
Region	Frequency (%)	Region	Frequency (%)
Antwerp	176 (17.57%)	Capellen	69 (9.24%)
Limburg	69 (6.91%)	Clervaux	16 (2.11%)
East-Flanders	139 (13.91%)	Diekirch	54 (7.26%)
Flemish-Brabant	84 (8.44%)	Echternach	27 (3.62%)
West-Flanders	98 (8.44%)	Esch-sur-Alzette	222 (29.57%)
Brussels Capital Region	92 (9.17%)	Grevenmacher	41 (5.46%)
Hainaut	114 (11.41%)	Luxemburg	170 (22.62%)
Liège	90 (8.99%)	Mersch	49 (6.49%)
Luxembourg	38 (3.83%)	Redange	34 (4.58%)
Namur	58 (5.84%)	Remich	36 (4.76%)
Walloon-Brabant	41 (4.08%)	Vianden	8 (1.10%)
		Wiltz	24 (3.20%)
France		**Germany**	
Region	Frequency (%)	Region	Frequency (%)
Grand Est	600 (100%)	Rheinland-Pfalz	548 (73.01%)
		Saarland	202 (26.99%)

	Belgium	Luxembourg	France	Germany	Total
Age cat					
18 – 25	5.76%	8.19%	5.18%	5.05%	6.06%
26 – 35	17.16%	24.80%	21.72%	17.88%	20.06%
36 – 45	16.98%	19.82%	18.46%	18.15%	18.23%
46 – 55	21.51%	19.93%	21.28%	19.89%	20.69%
56 – 65	14.14%	17.20%	22.21%	23.32%	18.66%
+65	24.46%	10.06%	11.15%	15.72%	16.29%
Mean age (Std Dev.)					
	51 (16.1)	45 (14.8)	47 (14.3)	49 (14.6)	48 (15.2)
Gender					
Male	64.45%	50.99%	59.08%	55.24%	57.93%
Female	35.12%	48.50%	40.77%	44.76%	41.78%
No answer	0.43%	0.51%	0.15%	0%	0.29%

The sample descriptives in table 8 show statistically significant differences for age and gender, which must be taken into account when interpreting the data. This is a result of the eligibility criteria, leading to exclusion of respondents, after the national representative collection of respondents. As an example, the age and gender distributions differ from national data, since gender is generally distributed around 50% men and 50% women, while here, more men were present in the sample).

The mean age and the drafted age categories differ between the countries ($p < 0.001$). Belgium shows a higher average driver age (largely explained by a higher presence of the 65+ age category and lower 26-35 age category), while Luxembourg shows a lower average driver age (largely explained by a higher presence of the 18-25 an 26-35 age categories and lower 65+ category). Germany and France show a higher presence of the middle aged category (56-65 years old).

Next, a higher presence of male drivers among the respondents is observed. Here, country differences were found to be significant ($p < 0.001$), showing a higher male presence for Belgium (quite large), France, and Germany, while Luxembourg knows a more even gender distribution. Note that this sample only consist of drivers that met all inclusion criteria, and hence are not representative for the general population.

Additional to the sample descriptives shown in table 8, additive background information was also analysed. Figure 11 shows the frequency in which a person drives or rides in Luxemburg. We assume that Luxembourgish inhabitants drive on Luxembourgish roads. For the other countries, the largest proportion of inhabitants mention to have driven once or twice in Luxembourg (44.3% for France, 51.7% for Germany, and 60.5% for Belgium). However, quite a large portion also indicates to sometimes (i.e. couple of times per year) drive in Luxembourg (42.8% for France, 39.1% for Germany, and 34.7% for Belgium). Only a relatively small portion of the drivers of each country drives often in Luxembourg (4.8% to 12.8%).

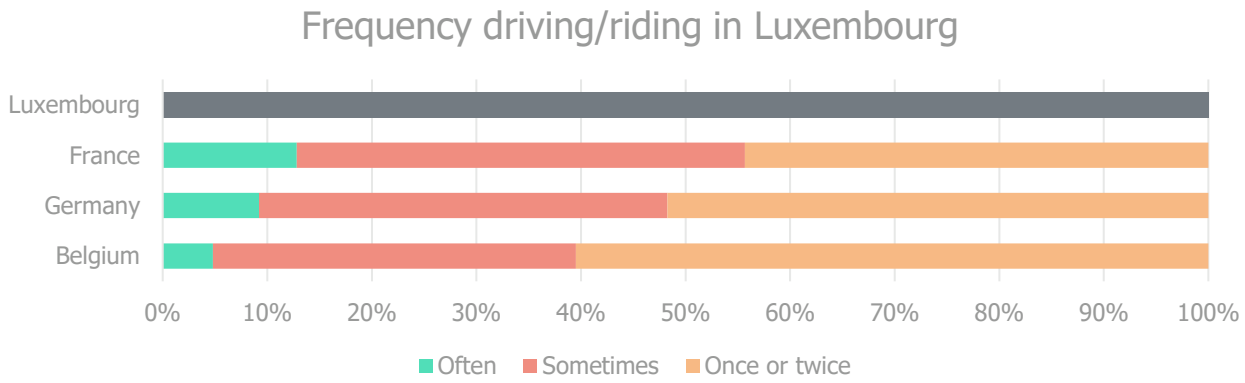

Figure 11: Frequency of driving or riding in the country Luxembourg

Also the frequency of driving certain transport modes was questioned (see figure 12). This was done to determine whether or not the use of other transport modes, compared to the car, could lead to different views on the rescue lane and lane filtering. On average, the car is used by most respondents. Less than 5% indicates not to use the car (anymore). Most respondents do not use trucks/busses and motorcycles (around 70%). However, roughly 30% of the respondents do drive a motorcycle or truck/bus additional to the car.

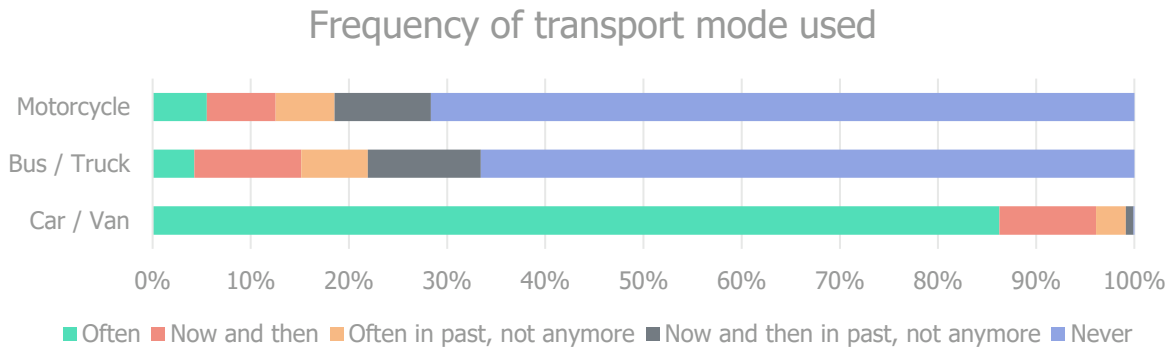

Figure 12: Frequency of the use of a motorcycle, bus/truck, and car/van

It is suspected that current and ex-motorcyclists can have differing opinions on the rescue lane, and lane filtering. Therefore the frequency of riding a motorcycle was taken into account driving. Figure 13 shows that a subdivision was made between those that ride a motorcycle (frequent or not), rode one in the past but not anymore, and those who have never ridden one. The presence of these categories can be found in figure 13. Additionally slightly more motorcyclists were collected in Germany, and slightly less in Belgium.

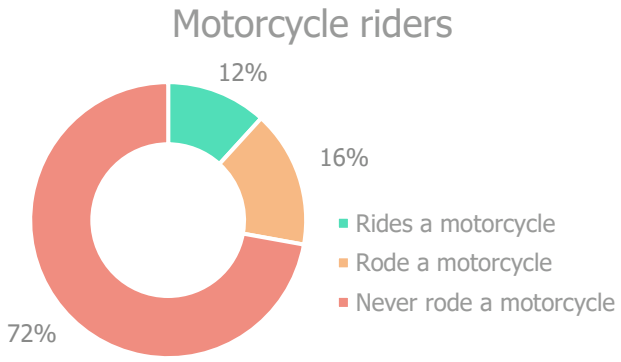

Figure 13: Incidence of motorcycle riders

5.3 General knowledge, attitudes, and behaviours concerning the rescue lane

Knowledge, attitudes, and behaviours were gathered concerning rescue lane. This concept was questioned generally, i.e. irrespective of the country of residence. It is therefore possible that respondents relate this section to their own country, or a country to which they associate the rescue lane concept (e.g. French drivers that visit Luxembourg, Germany or Belgium).

Figure 14 shows that on average 91.2% of the respondents are familiar with the concept of the rescue lane. However, statistically significant differences between countries can be observed. Familiarity with the rescue lane is highest in Germany and Luxembourg, while lowest in France. Belgium is situated in between. This is not surprising, since the rescue lane is longer present in Germany and Luxembourg, while only recently introduced in Belgium and absent in France. In that respect is the relatively high familiarity of the rescue lane concept among French drivers remarkable (i.e. 72.3% is somewhat familiar to the concept of the rescue lane), since the rescue lane is not legally present in France.

No statistical difference on the main effect for age ($p = 0.655$) and gender ($p = 0.07$) could be observed. No statistical difference on familiarity with the rescue lane could be identified either between (ex-)motorcyclists and non-motorcyclists ($p=0.145$).

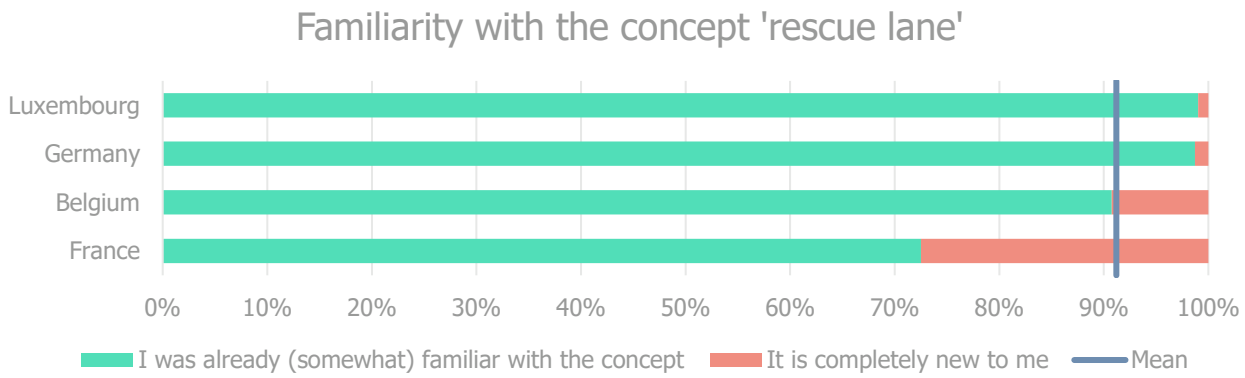

Figure 14: Familiarity with the concept of the rescue lane per country

Furthermore, compliance to the rescue lane was questioned to the drivers as well. This compliance was determined based on a multiple item question related to getting stuck in traffic. General compliance to the rescue lane seems to be present, as indicated in figure 15.

Most drivers indicate to immediately move to the side, or to always leave space even when no rescue service is present. However, 25.6% and 32.4% of the respondents respectively indicate to never or just sometimes leave space. On the other side of the spectrum, making use of the rescue lane, or getting tempted to use it, is only seldomly considered (less than 10% of the drivers). Additionally, driving towards the middle of the road to better understand the situation (i.e. moving towards the rescue lane, trying to see what happened) can be considered as a less common behaviour (although sometimes to often performed by 22.5% of the drivers).

Interestingly, only 51.1% of the respondents indicate never to forget to form a rescue lane. This indicates that an incorrect formation of the rescue lane is not a deliberate choice but often an action by mistake. Furthermore, quite some drivers indicate to only form a rescue lane when they see rescue services approaching (i.e. 67.5%) or to only form one when others do so as well (i.e. 46.9%). Possibly these respondents forget to form a rescue lane or believe that they still have sufficient space and time to form it when this becomes necessary.

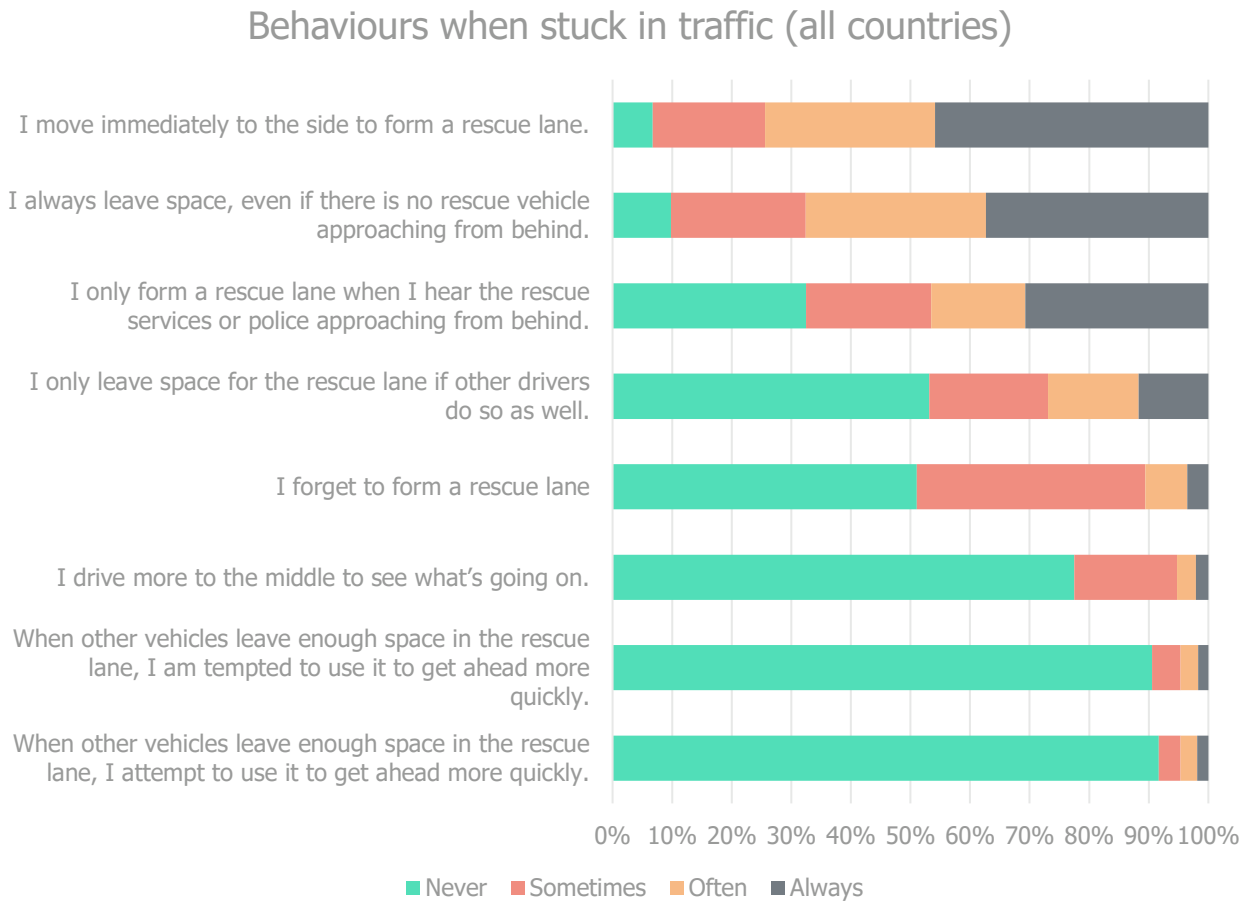

Figure 15: Self-reported rescue lane behaviours when drivers get stuck in traffic

Figure 16 shows that respondents from the respective countries behave differently in relation to the rescue lane. This was found to be statistically significant for all rescue lane items provided in the questionnaire.

The results show that countries with a nearly perfectly established rescue lane policy (i.e. Germany and Luxembourg) show more appropriate behaviours compared to their colleague drivers from Belgium and France. This tendency is especially prominent in the context of only forming a rescue lane when rescue services are approaching, or to only leave space for the rescue lane if other drivers do so as well. It is also apparent in terms of forgetting to form a rescue lane or driving towards the rescue lane to see what is going on. Also are drivers from France and Belgium more tempted to (or make) use of the rescue lane, and do they less often indicate to immediately open the rescue lane, or to form a rescue lane, even when no emergency services are approaching. While the differences with Germany and Luxembourg are smaller for these latter four items, they still reach statistical significance.

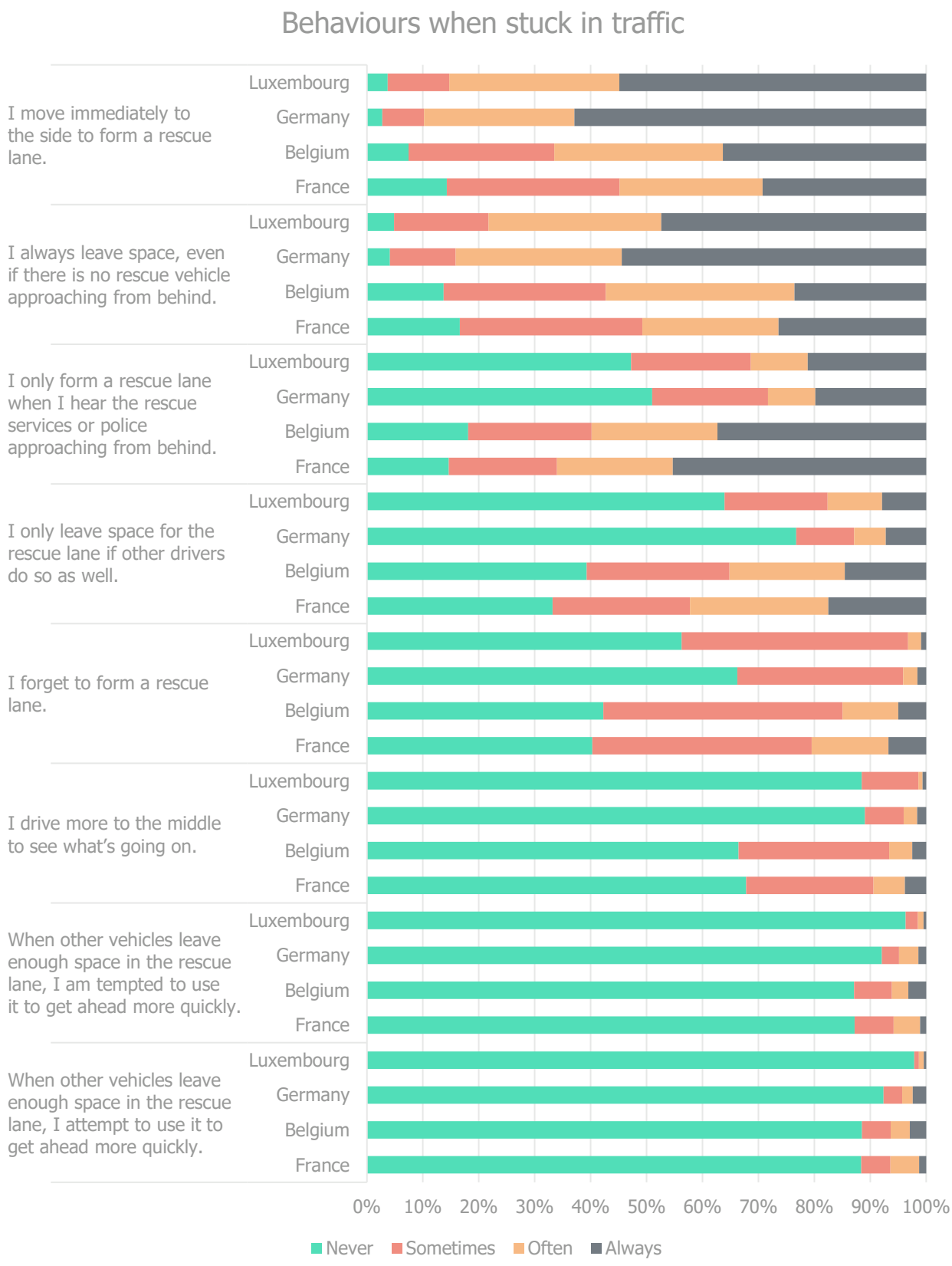

Figure 16: Self-reported rescue lane behaviours when drivers get stuck in traffic by country

Not only country differences were found. Statistically significant age and gender differences could also be identified ($p<0.05$). In terms of age, younger drivers (i.e. 28-26 and 26-35) are more inclined to drive towards the rescue lane to see what's going on, are more often tempted to make use of the rescue lane, attempt to use the rescue lane, and forget more often to form a rescue lane, compared to the age categories 56-65 and 65+. On the other hand, with an increasing age, drivers more often indicated to only move to the side when a rescue service approaches. For other items, no apparent differences were identified based on age. In terms of gender, men indicate more often to move towards the rescue lane than women (which could also have played a role in the lower score for Belgium, given the high presence of male drivers). For the other items, no gender differences were found.

Furthermore, statistically significant differences were found between drivers who ride a motorcycle versus those that do not. It seems that drivers who also ride a motorcycle are less strict in performing the appropriate rescue lane behaviour. This can be stated based on the fact that these drivers indicate more often to go towards the rescue lane to see what's going on, are more often tempted to make use of the rescue lane, and tend to forget more often to form a rescue lane. Contradictory however, they do more frequently form a rescue lane even when no rescue services are approaching, compared to drivers that never rode a motorcycle.

Lastly, the data indicates that familiarity with the concept of the rescue lane positively influences appropriate rescue lane behaviour (i.e. "knowledge effect"). This is in line with the country differences discussed in figure 16, where it was found that German and Luxembourgish drivers scored better on rescue lane behaviour.

As a last part of the general rescue lane section, respondents were asked to indicate to which extent different vehicles could be allowed into the rescue lane. Figure 17 shows that well known emergency services (i.e. ambulance, firefighters, and police) are very well accepted by other drivers to make use of the rescue lane. Maintenance vehicles, on the other hand, are also supported (69.6%), but to a lesser extent. Car drivers, in case of an emergency, and motorcyclists are less frequently accepted by other drivers to make use of the rescue lane, compared to emergency vehicles and maintenance/signalling vehicles. 53.5% of the respondents allow car drivers to make use of the rescue lane, in case of an emergency (although an emergency is difficult to verify in a real life situation). Motorcyclists are only accepted in the rescue lane by 16.2% of the drivers.

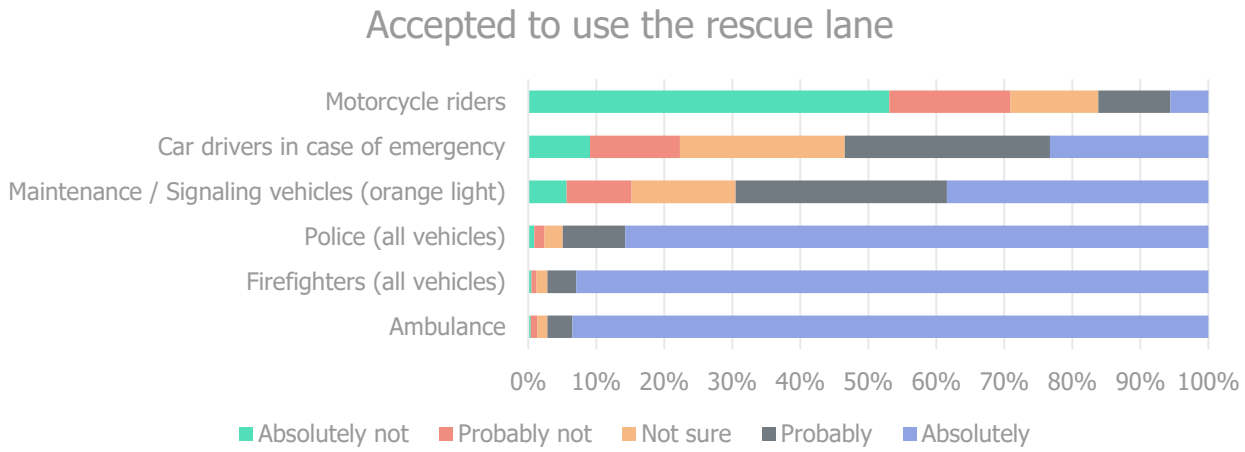

Figure 17: Road users that are accepted by drivers to make use of the rescue lane

Given the fact that the legislation on the rescue lane is interpreted more strictly in Germany and Luxembourg, compared to France and Belgium, differences were sought between the countries on road user acceptance in the rescue lane. Indeed, significant differences in road user acceptance could again be identified between countries. While police, firefighters, ambulances, and car drivers in case of an emergency, are equally often accepted in the rescue lane, regardless the driver's country of residence , more support for maintenance and signalling vehicles is found in France and Luxembourg compared to Belgium and Germany. For Luxembourg this could be related to the fact that signalling vehicles play an important role in securing the crash site and informing other road users. For motorcycle riders more support in Belgium and France was found, compared to Germany and Luxembourg, which could be explained by the legality of lane filtering in these countries (be it experimentally in France), resulting in a higher exposure of motorcyclists in the same space that is normally reserved for a rescue lane. However, support for motorcyclists in the rescue lane is still relatively low in all countries.

Significant differences were also found based on age, gender, and whether a driver also rides a motorcycle. As age increases, slightly more drivers accept police, firefighters, ambulances and maintenance/signalling vehicles to make use of the rescue lane. As age decreases motorcyclists and car drivers in case of an emergency are slightly more accepted in the rescue lane. Female drivers accept more often car drivers in case of an emergency in the rescue lane, while male drivers accept more often a motorcyclist in the rescue lane. Current and former motorcyclists more often accept a motorcyclist, and a car in case of an emergency in the rescue lane.

Lastly, drivers who indicated to be familiar with the concept of the rescue lane, are more strict towards access of non-emergency services in the rescue lane. They less frequently accept motorcyclist, signalling vehicles, and car drivers in case of an emergency to make use of the rescue lane.

5.4 Behaviours on the respect of the rescue lane

One of the goals of this research report is to determine the impact on the rescue lane if lane filtering would be legalised in Luxembourg. To do so, the questionnaire incorporated stated behaviours of drivers in specific situations, applied to a Luxembourgish context. Here, cases were presented using pictures. For each case, a picture was shown with or without a motorcyclist present. A full overview of the questions can be found in annex I. Afterwards, the effect of the presence of a motorcyclist on the behaviours could be investigated making use of an ordered logistic regression model. Through this model, individual effects of variables of interest can be identified controlling for one another (i.e. motorcyclist present, country effect, gender effect, age effect, etc.).

Figure 18 shows the stated behaviours that were asked in the context of moving towards the rescue lane. Overall, quite compliant rescue lane behaviour was found. The data shows that, in general, that most drivers choose to move to the outer side of their lane (i.e. away from the rescue lane), or stay at the outer side of the rescue lane. Driving towards the rescue lane is only considered by roughly 12% of the drivers. Staying in the lane without moving would be performed by 28.5% of the drivers.

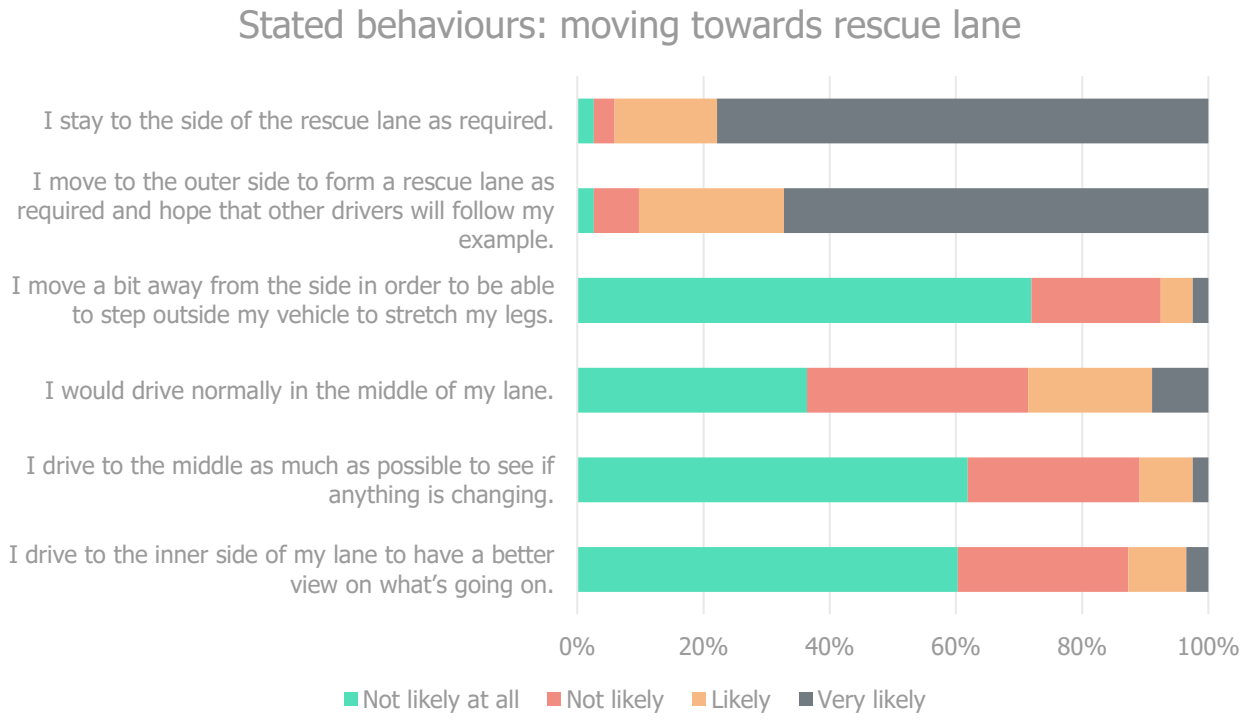

Figure 18: Stated behaviours by drivers in a traffic jam in relation to moving towards the rescue lane

Figure 19, shows the stated behaviours that were asked in relation to using the rescue lane. While 20% of the drivers consider to move towards the rescue lane to spot the next highway exit (therefore potentially hindering approaching emergency services), more than 90% of the respondents indicates to immediately form a rescue lane, to stay where they are, and to not use the rescue lane. Therefore, in general, it can be stated that most drivers comply with the rescue lane and do not consider making use of it.

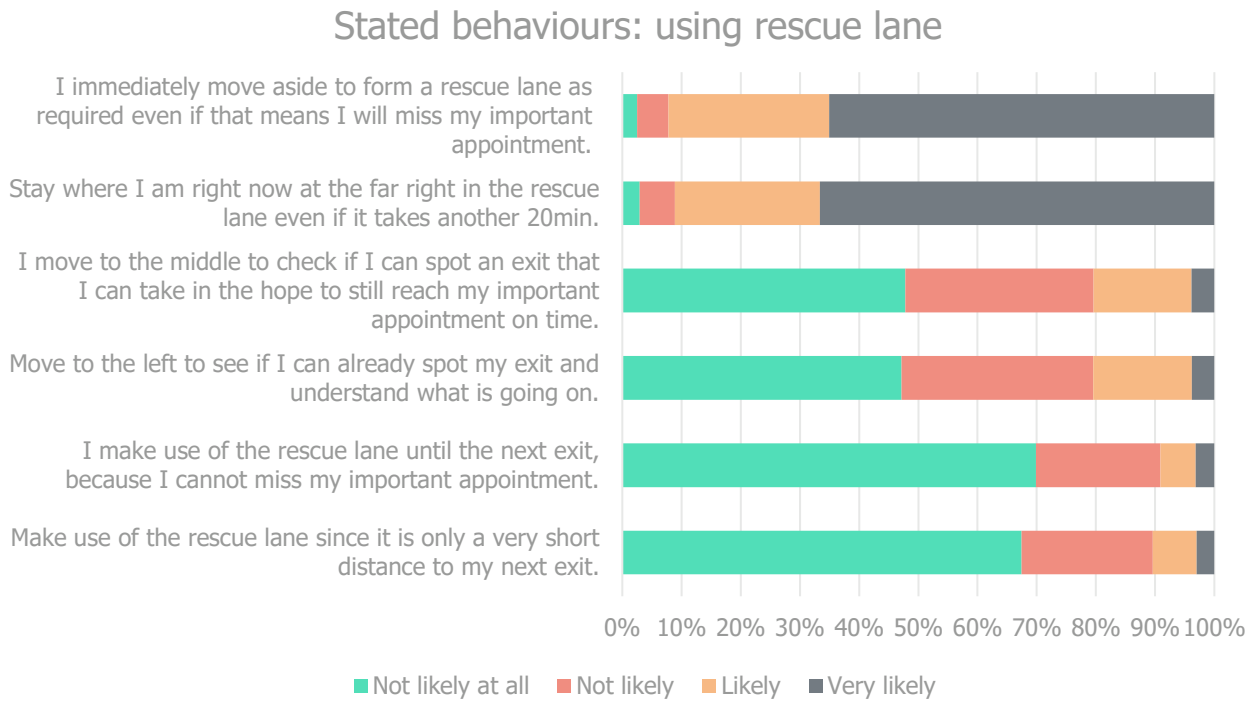

Figure 19: Stated behaviours by drivers in a traffic jam in relation to considering using the rescue lane

Figure 20 finally shows the stated behaviours that were asked in relation to blocking the rescue lane. In general, it is found that most drivers form a rescue lane as required (i.e. approximately 95%). Drivers who are already situated away from the rescue lane do not really consider moving their car back to the middle to see if someone else would make use of the rescue lane. However, 36% of the drivers indicate that they would stay where they are in their lane to spot someone else using the rescue lane. Around 12% of the drivers considers blocking all available space in the rescue lane to let nobody pass, except emergency services. Blocking the rescue lane is behaviour that must be avoided at all costs since it takes time to move out the way in standstill traffic.

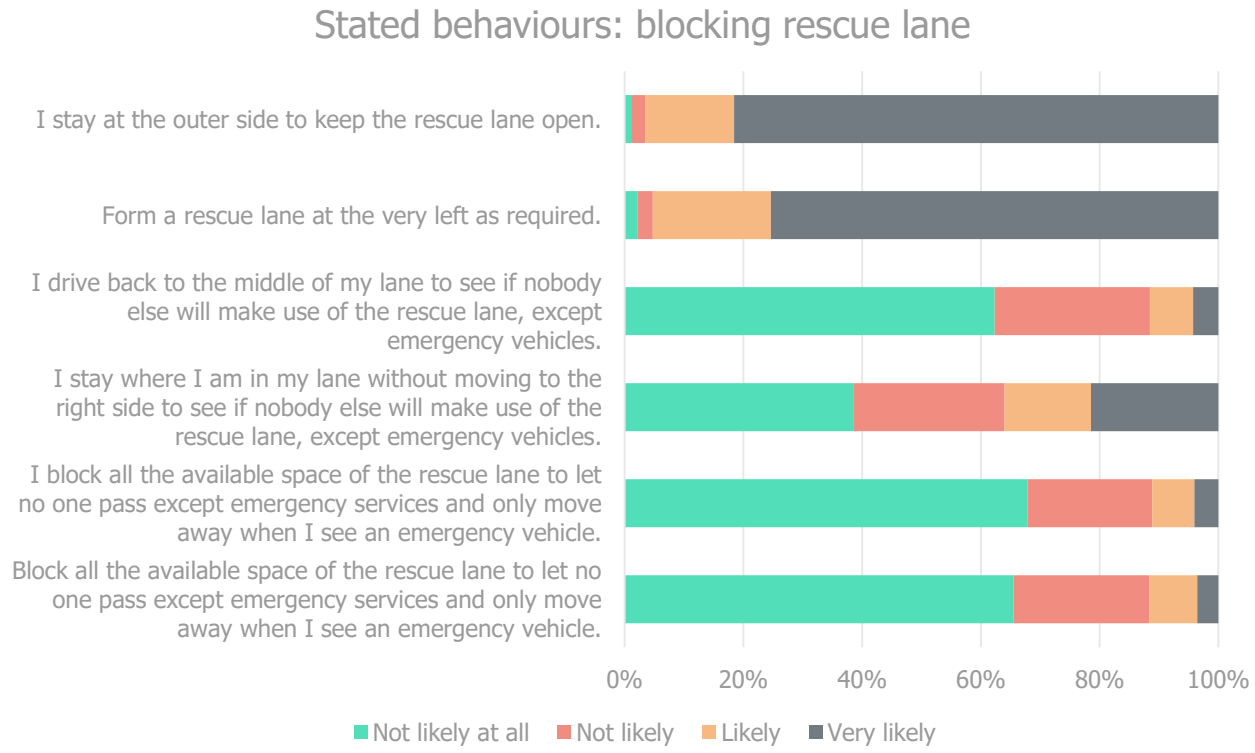

Figure 20: Stated behaviours by drivers in a traffic jam in relation to considering blocking the rescue lane

To determine the impact of the presence of a motorcyclist, together with other variables which were believed to impact attitudes and behaviours of drivers, an ordered logistic regression was performed. Through this model, individual variables of interest can be tested controlling for other variables. Therefore individual effects could be explored. A clarification of the chosen regression model, as its output, is available in annex II.

In only two of the eighteen items provided to the respondents, a statistical effect caused by the presence of a motorcyclist in the rescue lane could be found on the self-reported rescue lane behaviour of drivers. In other words, drivers did not indicate more often to perform inappropriate behaviours towards the rescue lane when a motorcyclist was present in the rescue lane. More specifically the impact was only found on two items that both described situations in which a driver would not completely move to the outer side away from the rescue lane. An impact on very inadequate behaviours was completely absent (e.g. blocking passage, making use of the rescue lane). As a result, it can be stated that the mere presence of a motorcyclist in the rescue lane has little to no effect on the stated behaviour of other drivers stuck in that rescue lane.

The regression model showed that country influences play the biggest role. The data shows that drivers from Luxembourg and Germany are more likely to perform the adequate behaviour in relation to the rescue lane (e.g. immediately opening up, no blocking, not making use of it, etc.). Drivers from France and Belgium are more likely to perform inadequate rescue lane behaviour. This is in line with the general attitude and behaviour questions explored in the previous section.

Age effects were found to be significant but small (i.e. a p-value smaller than 0.05 was found, but the odds-ratio situated very close to 1). Therefore, age effects were not seen as an impacting factor with adequate rescue lane behaviour in these specific cases. Next, for some items (i.e. driving towards the rescue lane, moving slightly towards the rescue lane to get out the car and stretch the legs, making use of the rescue lane), female drivers were found to be more likely to perform appropriate rescue lane behaviour than male drivers. This is also in line with the general attitude and behaviour questions explored in the previous section.

General compliance to the rescue lane was largely present within respondents that are both car drivers as well as motorcyclists. However, they were found to perform some inadequate behaviours more than car drivers who did not ride motorcycles. This was the case for behaviours relating to driving towards the rescue lane to see what is going on, to become tempted to use the rescue lane, to block passage for others, and not staying adequately at the side of the rescue lane. It has to be noted that group of drivers formed a relatively small portion of the sample.

Similarly, car drivers that also are bus or truck drivers, were also found to perform some inadequate behaviours more than 'only-car' drivers. Here as well, general compliance to the rescue lane was still largely present within these car driving truck or bus drivers.

Lastly, drivers that less frequently visit Luxembourg (i.e. drivers that do not regularly drive in Luxembourg) were found to be more likely to perform adequate behaviour in relation to the rescue lane. It is assumed that a lack of knowledge, or acknowledgement that other rules apply compared to the country of origin, leads to more careful driving behaviour.

Summarised and based on our data, appropriate behaviour in relation to the rescue lane seems strongly determined by the country of the respondents' residence, ceteris paribus. We assume that the longstanding history of the relevant regulation in a country (i.e. the rescue lane concept is longer present in Germany and Luxembourg), results in a higher respect and more appropriate behaviour towards the rescue lane. The mere presence of motorcyclists that filter between lanes, does not seem to impact this. It seems that performing appropriate behaviour towards the rescue lane (i.e. the urge to comply to the regulation), outweighs impulsive actions as a result of the behaviour performed by others.

5.5 Knowledge, attitudes, and behaviours concerning lane filtering

For this part of the questionnaire, data was collected country specific, where drivers had to answer lane filtering items respective to their own living country. Therefore, not only the impact on the rescue lane was important to investigate, but knowledge, attitudes and behaviours towards lane filtering were relevant as well to form a total picture.

5.5.1 Knowledge about lane filtering

To start, the familiarity with the concept of lane filtering was explored. Drivers were given information on lane filtering (see table 9) and asked whether or not they were familiar with the concept. Additionally, drivers were asked whether they were aware that rules apply with lane filtering.

Table 9: Information provided on lane filtering in the questionnaire

A motorcyclist is lane filtering if:	Lane filtering is not:
– traffic is moving slow or has come to a full stop in a cue or traffic jam. – he/she rides between two lanes of vehicles at a slow/adapted speed. – he/she rides between the two most left lanes.	– riding at very high speeds in between traffic (= weaving) – passing on the breakdown lane – passing on the left side of the most left lane

On average, 70.9% of the respondents indicated to be familiar with the concept of lane filtering, but only 48.1% indicated being aware that some rules apply to lane filtering. Figure 21 shows the country differences. In France and Belgium, where lane filtering is longer present and legally formulated (although experimentally in France), slightly more knowledge on the rules can be seen compared to Luxembourg. German drivers seem to be less familiar with lane filtering, while also being least aware that rules apply towards the behaviour. In Luxembourg, contrary to Germany (where lane filtering is illegal), lane filtering is common practice. This can explain the higher familiarity with the concept within Luxembourgish drivers compared to German drivers, while having a lower awareness of rules towards the behaviour, compared to French and Belgian drivers.

An age effect was not present in these data. However, in terms of gender, men were more familiar with the practice and also more aware of rules towards the practice. Drivers, who also ride a motorcycle, were also more familiar and more aware of rules.

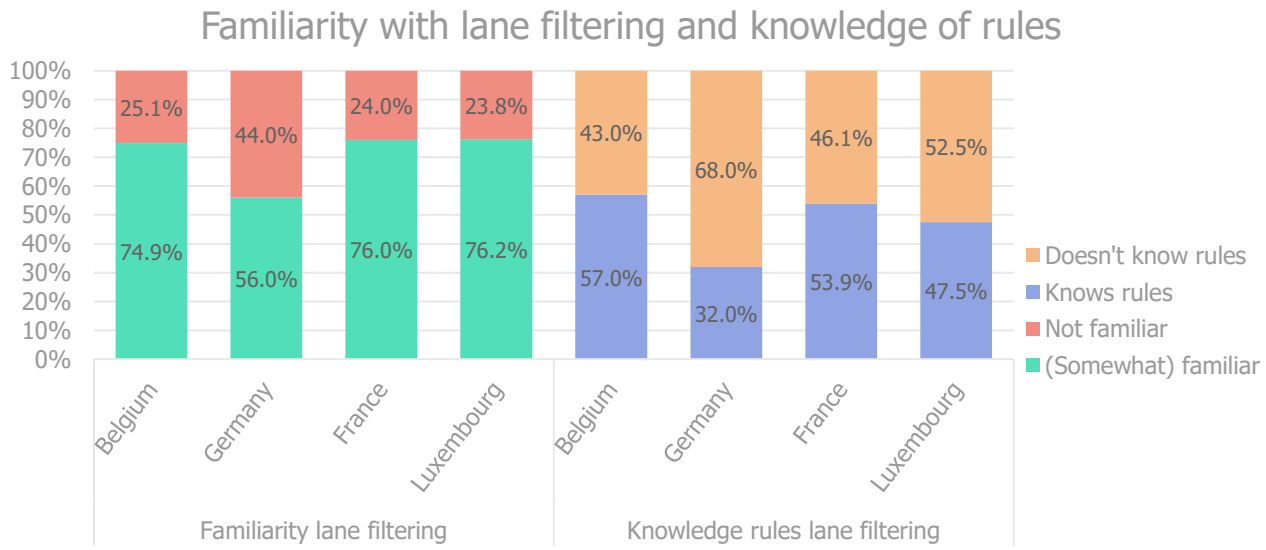

Figure 21: Familiarity with the concept of lane filtering and awareness of rules regarding the concept

Additional findings are in line with the hypothesis stated with figure 21, where it was mentioned that the common practicality of lane filtering and it's legal acceptance could increase the familiarity with the concept and awareness about rules. Figure 22 shows that in countries, such as Luxembourg, France and Belgium, lane filtering is indicated by the drivers to occur quite often, compared to Germany. In these countries, a higher familiarity with lane filtering could also be observed. An additive statistical analysis showed that a higher occurrence (or exposure) to lane filtering also led to more familiarity with the concept itself; as well as more self-estimated knowledge on the appliance of rules. Not surprisingly, being more exposed to lane filtering as a driver thus seems to lead to more familiarity and knowledge about the rules concerning the behaviour.

In Luxembourg, foreign drivers get less commonly exposed to lane filtering, compared to the exposure in the country of residence. Out of these foreign drivers, French drivers indicate most often being exposed to lane filtering in Luxembourg, compared to drivers from other countries.

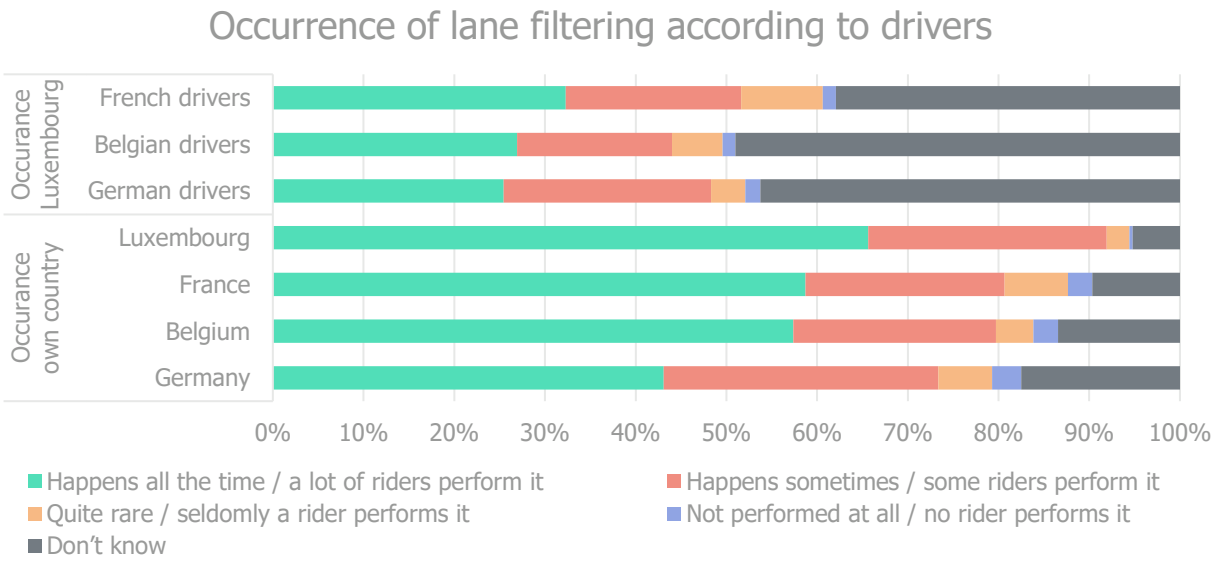

Figure 22: Occurrence of lane filtering according to the drivers both in their country of residence as well as in Luxembourg

Elaborating further on knowledge, drivers were asked whether they knew the legal status of lane filtering in their country of residence. Figure 23 shows that a large majority of the respondents, regardless of the country, does not know the legality of lane filtering in their country (i.e. 28.7% to 42.3%). Nor the legal situation in Luxembourg is known (i.e. 47.9% to 57.7%), highlighting that knowledge on lane filtering in Luxembourg from foreign drivers is very limited to date. The country differences observed in figure 23 were found to be statistically significant ($p<0.001$).

Figure 24 simplifies how many drivers answered correctly on the legality of lane filtering in their country of residence. Drivers in Belgium are most correct concerning the legality of lane filtering in their country, while drivers in France score the lowest. The latter can be explained by the confusing situation in France resulting from the current lane filtering experiments. However, Germany and Luxembourg also show low scores on the correct knowledge of the legality of lane filtering, with a lot of drivers indicating not knowing the legal status.

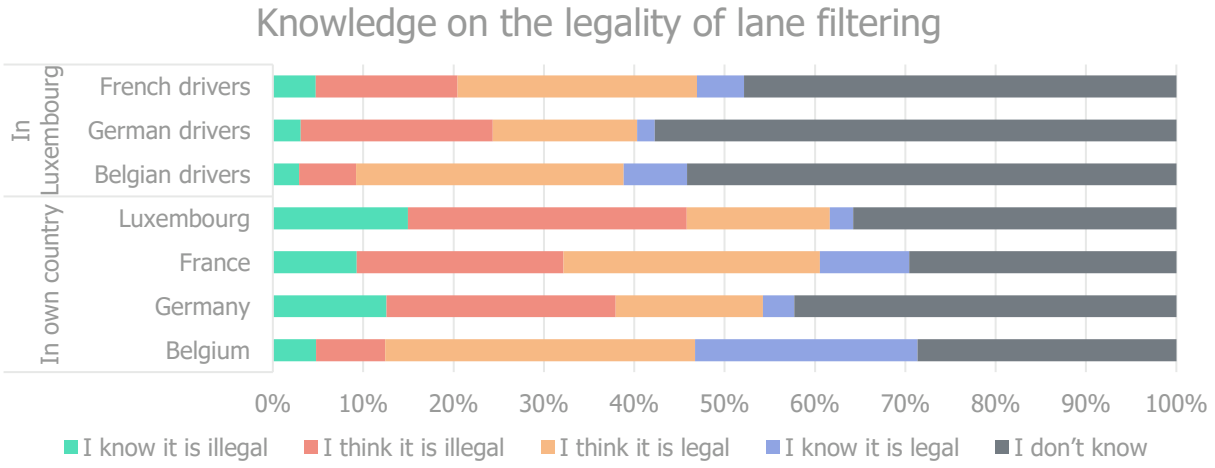

Figure 23: Knowledge on the legality of lane filtering for the own country and Luxembourg

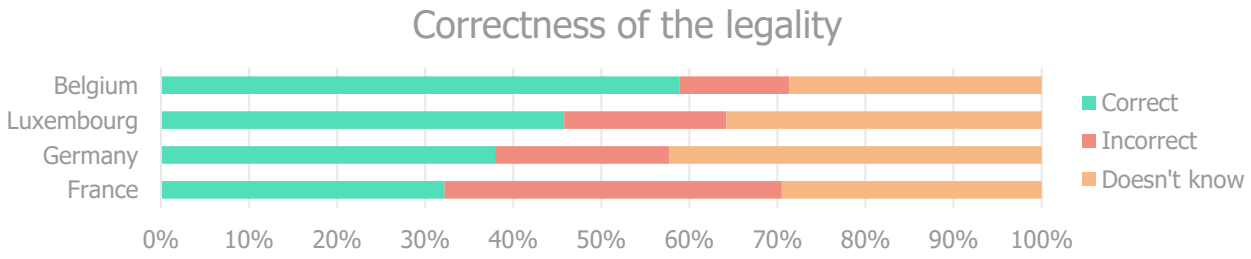

Figure 24: Correctness of the legality of lane filtering for the own country

Additional analyses showed that those being more familiar with the concept of lane filtering, or those indicated to know the rules (see figure 21), answered more often correctly on the legality of lane filtering ($p<0.001$). However, still, 28.1% of those indicating to know the rules, answered wrongly on the legality in their country while 15.6% indicated not to know the legal status. This means that, only 27% of the total sample (N=3100) knew that rules applied to lane filtering while also answering correctly on the legality in their country. The remaining 73% either had to guess (of which some answered correctly), honestly did not to know, or answered incorrect (while indicating to know that rules apply).

This tends to show an issue related to correct knowledge on lane filtering, which could be addressed by legalising the behaviour and communicating about possible rules. An example for this is Belgium, which is the only country that formally legalised the practice out of the four countries included. In fact, Belgian drivers were found to give most often the correct answer, while indicating to know that rules apply concerning lane filtering (i.e. 42.6% of then Belgian drivers answered correctly while indicating to know that rules exist, while this was 13.7% for German drivers, 17.7% for French drivers, and 27.2% for Luxembourgish drivers).

Age and gender differences were also found. Namely, for age, younger drivers answered more often correctly, while older drivers more often indicated not to know the legal status ($p<0.001$). On the other hand, men answered more often correct than women ($p<0.001$).

5.5.2 Attitudes towards lane filtering

Related attitudes to lane filtering were also queried, only after the knowledge section in the questionnaire, to make sure that each respondent had an adequate understanding of correctly performed lane filtering. Specific attitude items were formulated focussing on general attitudes per country, the (possible) legalisation per country, and attitude towards decision-making on the topic in Luxembourg in specific.

Firstly, specific attitudes were questioned through different positive and negative statements about lane filtering. By doing so, the degree of criticism on lane filtering could be determined. Table 10 gives an overview of the items that were constructed to determine the level of criticism. In order to ease the analyses, given the large number of items, a factor analysis[6] was performed to determine whether these items were able to capture one single dimension (i.e. criticism on lane filtering). Afterwards, further analyses were performed.

Table 10: Specific attitudes (positive and negative) questioned in relation to lane filtering

Specific attitudes in relation to lane filtering	
+	Lane filtering and riding a motorcycle go hand in hand
+	Lane filtering improves traffic flow for everyone
+	Lane filtering contributes to less air pollution
+	Lane filtering is safe
+	Motorcyclists tend to ride respectful when they filter between lanes
–	Lane filtering is asocial
–	Lane filtering is a cause for accidents
–	Motorcyclists who filter between traffic are not respecting the rescue lane
–	Only motorcyclists benefit from lane filtering
–	Lane filtering is unfair to other drivers stuck in traffic
–	I'm against lane filtering
–	It is dangerous when a car and motorcycle are (nearly) on the same lane
–	Lane filtering is the same as overtaking on the right and should therefore be forbidden/remain forbidden
Answering scale: I fully disagree – I disagree – I agree – I fully agree – No opinion	

The factor analysis showed that the items 'Lane filtering and riding a motorcycle go hand in hand' and 'Only motorcyclists benefit from lane filtering' did not score sufficiently high to include in the analysis. They are in other words not related to positive or negative views (or pro- and contra argumentation) towards lane filtering. All other items, on the other hand, loaded positively on the dimension of 'criticism towards lane filtering'. This was also reflected in the high Cronbach's alpha for these items ($\alpha = 0.902$). A lane filtering scale was created based on the arithmetic mean of all items, with scores normalized between 0 and 1, with high values indicating highly critical views of lane filtering. Hereafter, the results will be discussed.

[6] Factor analysis is a technique that is used to reduce a large number of variables, that measure the same concept, into fewer numbers of dimensions or factors. A factor is thus a set of observed variables that have similar response patterns.

First, the overall score on the lane filtering scale was found to be equal to 0.569 (SD = 0.223), indicating that most respondents in the survey situate somewhere in-between critical and positive views towards lane filtering (i.e. not strictly against, but not strictly in favour).

Besides the overall finding, statistical differences were observed between countries. Drivers from Belgium were more neutral towards lane filtering (i.e. a score of 0.499), while drivers from Germany were more critical (i.e. a score of 0.625). France and Luxembourg situated somewhere in-between with a score of 0.599 and 0.567 respectively. This seems in line with the support of motorcycles in the rescue lane as discussed with figure 17. For the item 'Lane filtering and riding a motorcycle go hand in hand' (excluded from the lane filtering scale) more favourable scoring was found for Belgian drivers, while differences between the other countries were non-existent. On this item, Belgian drivers were, thus again, more lenient.

No age effect could be observed. For gender, women were found to show more criticism towards lane filtering than men. Men also frequently indicated that 'Lane filtering and riding a motorcycle go hand in hand'. It is possible that this gender difference is confounded by motorcycle riding, as the data showed that (ex-) motorcyclists, to no surprise, support lane filtering more, while non-motorcyclists showed more criticism.

These general attitudes also reflect on the attitudes towards the legalisation of the practice. In general, an equal number of supporters and opponents for the legalisation was found, since 35.9% believes lane filtering should be legalised in all countries, while 36.3% opposes and 27.9% has no opinion. On the other hand, 36.2% believes that a legalisation would cause problems, while 34.7% does not and 29.11% has no opinion. Figure 25 shows that Belgian drivers are more in support of the legalisation of lane filtering, while German riders are less supportive. Luxembourg and France situate themselves in between. A significant part of the drivers (i.e. 19.6% to 35.1%) indicated for each country, to have no specific opinion on the matter. However, support tends to be lowest in Germany and France.

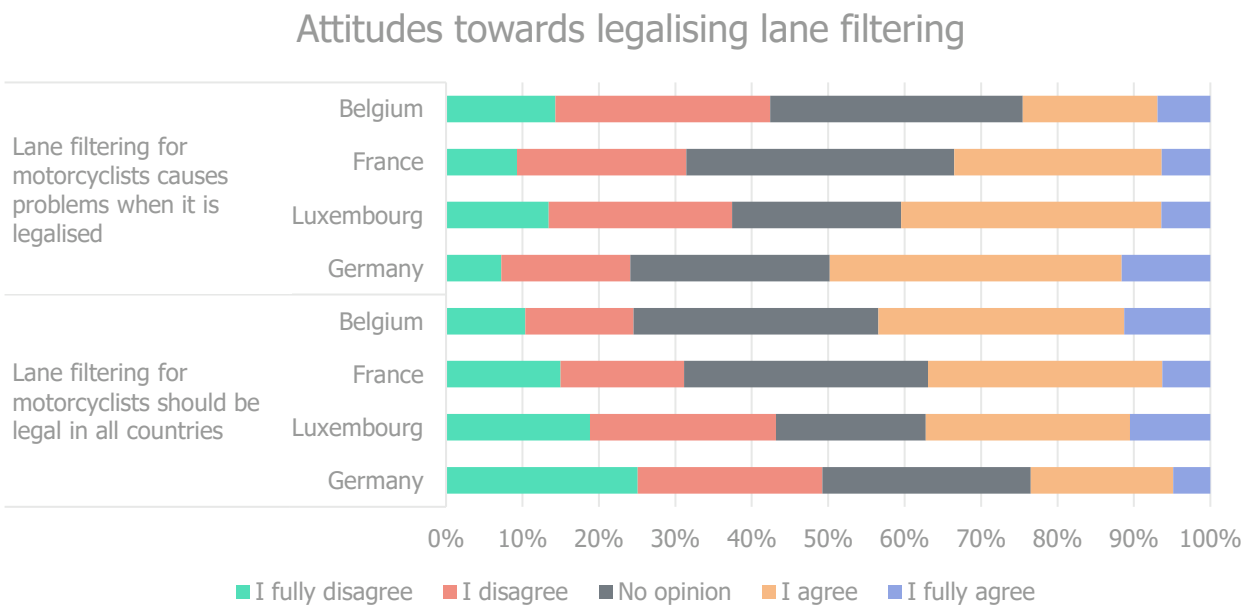

Figure 25: Attitudes towards the legalisation of lane filtering

With regards to legalisation, men tend to show more support compared to women, as do motorcyclists. Based on age, differences were also found, but were not interpretable, as they did not show a clear trend.

Lastly, attitudes towards the legalisation of lane filtering in Luxembourg were gathered. Figure 26 illustrates attitudes in the context of three statements. In general it shows that one out of five, to one out of four, drivers indicate not having a specific opinion towards the legalisation of lane filtering in Luxembourg. 46.6% of the drivers believe that lane filtering could cause problems in Luxembourg when it would be legalised. As a result, 35.3% of the drivers indicate that it wouldn't be a good idea if lane filtering would get legalised. On the other hand, 32% believes that lane filtering won't cause a problem when legalised, resulting in 40.3% of the drivers believing it would be a good idea to legalise lane filtering. Interestingly, 31.4% indicates note to care about the decision made in Luxembourg, while 22.5% indicates not to have an opinion. 46.1% indicates to care about the future situation.

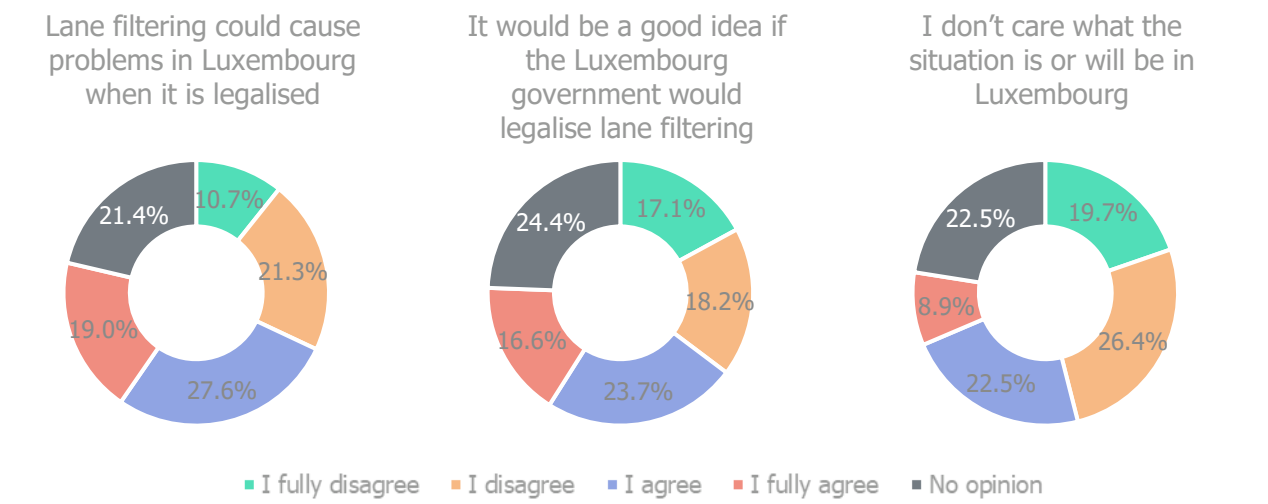

Figure 26: Attitudes towards legalising lane filtering in Luxembourg (not country specific)

Here again, country differences were statistically significant. Especially respondents from Germany do not support a legalisation of lane filtering in Luxembourg (46.4% thinks it would not be a good idea, while 57.5% believes it could cause problems). Luxembourgish drivers also largely believe it would not be a good idea to legalise lane filtering (i.e. 46%), arguing it could result in problems (i.e. 51.3%). Drivers from Belgium and France tend to be more positive, although they also frequently indicate not to care about possible future decisions in Luxembourg.

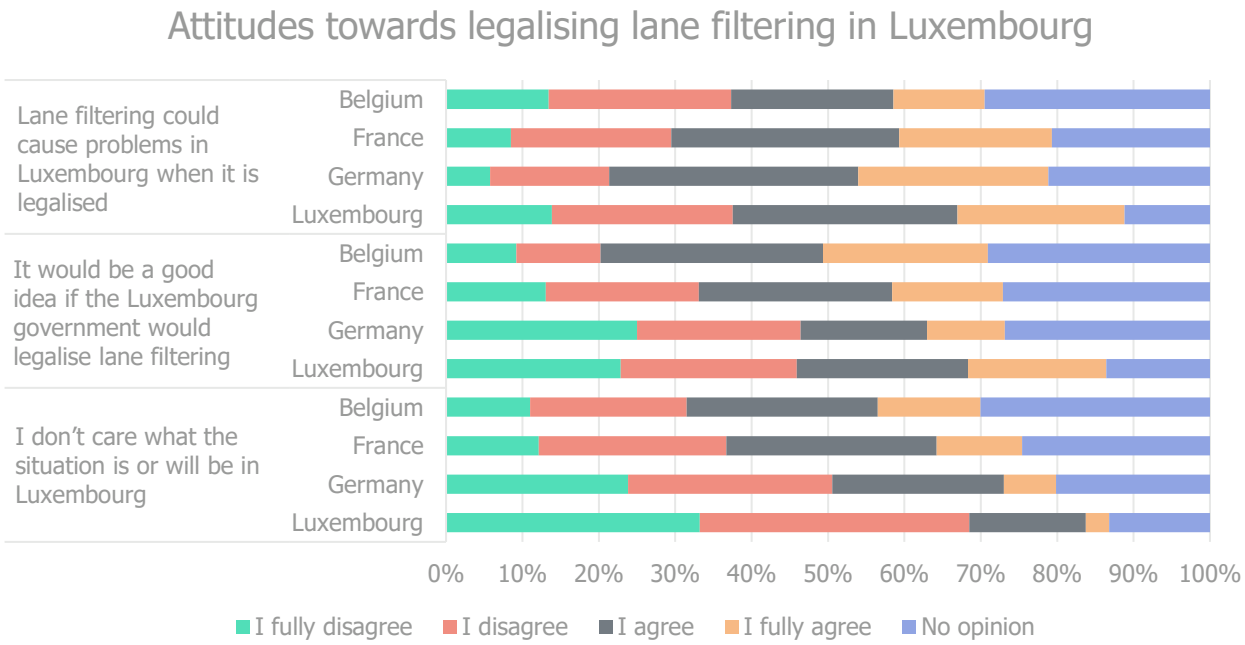

Figure 27: Attitudes towards the legalisation of lane filtering in Luxembourg (country specific)

Lastly, men were found to be more in favour of lane filtering in Luxembourg than women. Furthermore, they also tend to care less about what will be decided in Luxembourg. Age differences were also found, but were again not interpretable, as they did not show a clear trend.

Motorcyclist were clearly more in favour of legalising lane filtering in Luxembourg and tend to care more about the decisions made in Luxembourg. This is logical, as a potential legislation can benefit motorcyclists.

5.5.3 Behaviours towards lane filtering

The final part of the questionnaire focussed on behaviours of car drivers related to lane filtering performed by motorcyclists. Specific behaviours were questioned, tailored to situations that are relevant for lane filtering motorcyclists. Also, specific coping behaviours related to lane filtering (i.e. in order to avoid lane filtering) were queried.

Figure 28 gives an overview of the occurrence of certain behaviours that car drivers perform, relevant for lane filtering motorcyclists. In general, good compliance is observed. More than nine car drivers out of ten often to always indicate to use the indicator to change lanes, pay attention to other road users in their vicinity, avoid sudden manoeuvres, check mirrors, and check blind spots as good as possible. However, some other behaviours are still far from perfect. It is important for lane filtering, that drivers avoid distraction by electronic devices, that can possibly lead to missing a lane filtering motorcyclist. Only 69.4% indicates to often or always avoid anything that can distract the driver. The creation of a rescue lane, and following the speed limit also indicate room for improvement (roughly 25% indicates to not follow the speed limit or to not move aside to create a rescue lane). This rescue lane is not only important for rescue services, but can also help to create sufficient space for motorcyclists, as it is shown in figure 28 that 32.2% indicates to never or sometimes move aside to let a motorcyclist pass who legally filters between lanes.

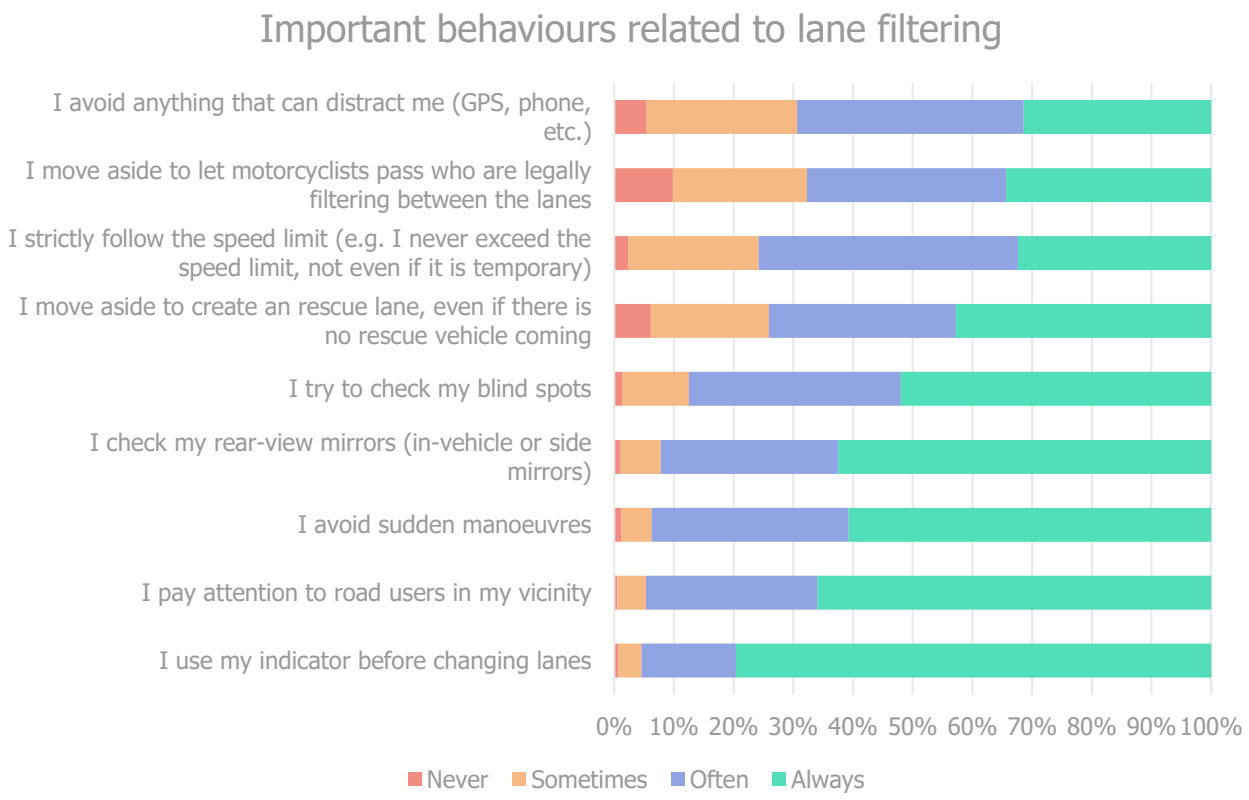

Figure 28: General overview of the occurrence of certain behaviours of car drivers that are relevant for lane filtering

Figure 29 shows differences between the countries, for which a statistically significant difference could be observed ($p<0.05$). Here, Belgian and French drivers show more courtesy towards lane filtering motorcyclists compared to German and Luxembourgish drivers. (i.e. I move aside to let motorcyclists pass who are legally filtering between the lanes). German and Luxembourgish drivers stick more strictly with the rescue lane legislation (i.e. I move aside to create a rescue lane, even if there is no rescue vehicle coming) compared to Belgian and French drivers. Distractive elements seem to be avoided a bit more by Belgian and German drivers. French and Belgian drivers also more frequently indicate to stick to the speed limit, while German and Luxembourgish drivers seem to pay more attention to other road users in their vicinity. Indicator use does not differ much, except for Belgian drivers that slightly more often use their indicators when switching lanes compared to the other drivers.

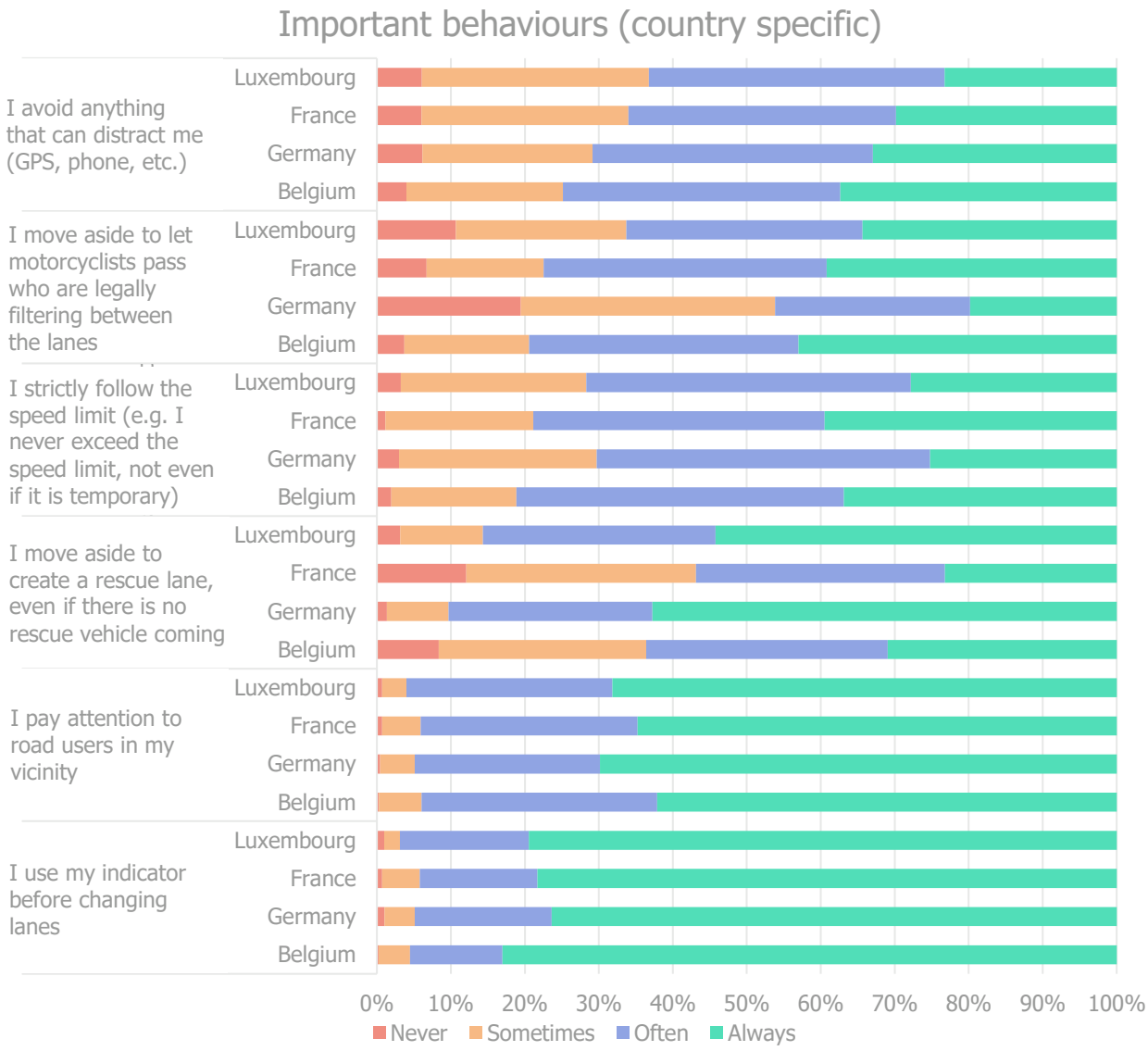

Figure 29: Country overview of the occurrence of certain behaviours of car drivers that are relevant for lane filtering

Additionally, age and gender difference could also be identified. Data showed that younger car drivers were less strict, compared to older drivers. Younger drivers only indicated more frequently to move aside to form a rescue lane, even if no rescue services are coming, which is consistent with previous findings where older drivers indicate more often to only make way when an emergency vehicle approaches. Based on gender, a noticeable difference was only found for moving aside to let motorcyclists pass who are legally filtering between the lanes, in which men indicated to perform this behaviour more frequently than women.

Furthermore, differences between drivers who ride a motorcycle and those who do not were found. Non-motorcyclists indicated more frequently to use their indicator before changing lanes compared to motorcyclists. Car driving motorcyclists indicated more frequently to move aside to let motorcyclists pass who are legally filtering between the lanes (i.e. respect towards other fellow riders), and indicate more often to move aside to create a rescue lane, even when no rescue vehicle is coming. The latter is also consistent with the previously discussed findings in this questionnaire in section 5.3.

Lastly, behaviours of car drivers in relation to deliberately avoiding lane filtering were questioned. Figure 30 gives an overview of possible behaviours that can be performed, or choices that can be made, to avoid an encountering with lane filtering motorcyclists. In general, car drivers chose not to obstruct lane filtering motorcyclists and do not change their travel behaviour because they could come across lane filtering motorcyclists. However, they do seem to be more cautious of choosing a driving lane or staying in a driving lane to avoid an occurrence with motorcyclists.

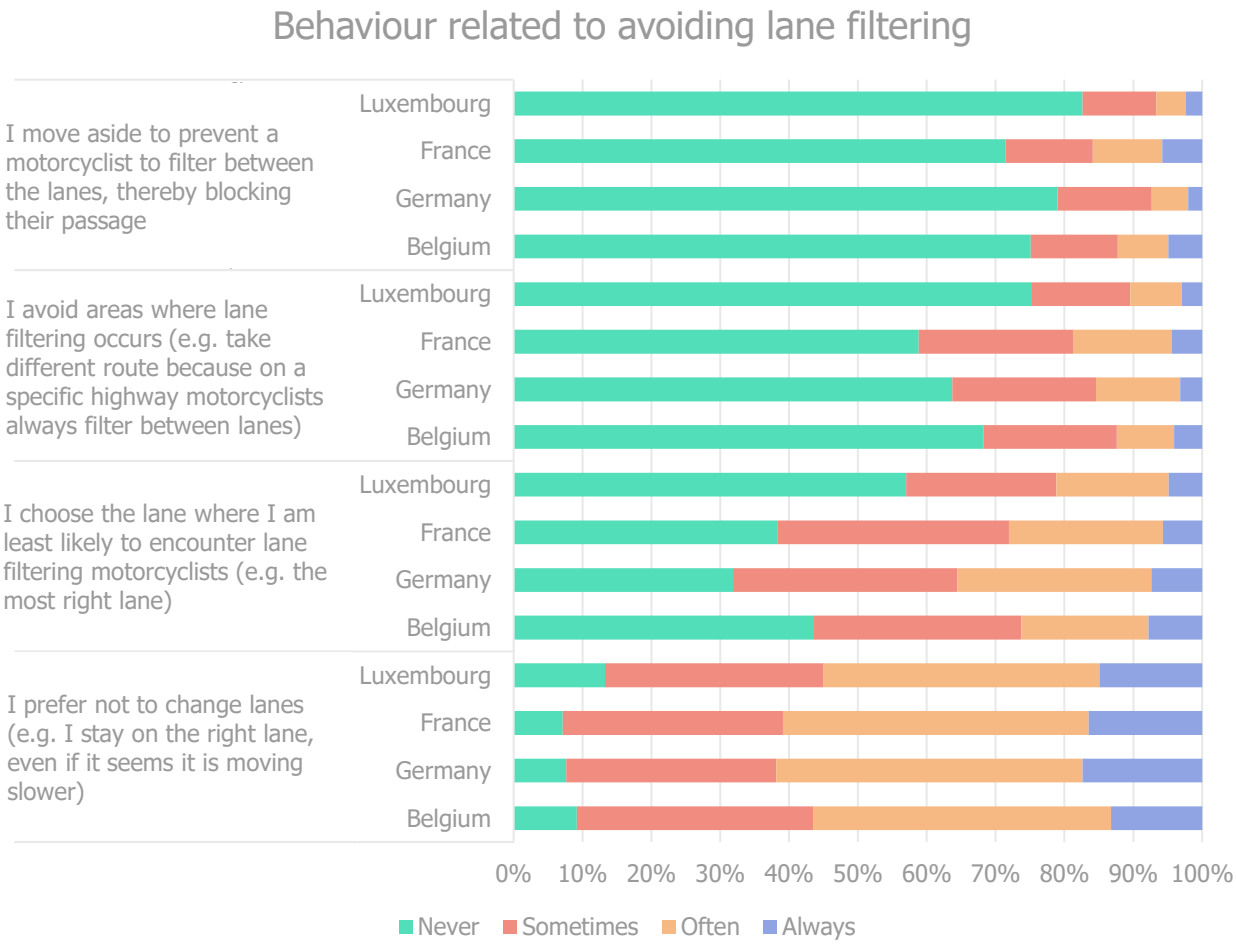

Figure 30: Behaviours of car drivers related to avoiding an encountering with lane filtering motorcylists

While age differences were less clear, since they did not show a clear trend, gender differences could be distinguished. Men indicated more often to prefer not changing lanes than women. Car drivers, who also ride a motorcycle, more often deliberately indicated to choose a lane or avoid an area where lane filtering by motorcyclists is performed. They also more frequently indicated to block the passage for motorcyclists, which was consistent with the previous findings in section 5.4, where car drivers that also ride a motorcycle were found to be more inclined to block passage for others in the specific uses cases that were provided.

6 Discussion

Luxembourg is a country with a very specific traffic situation, due to its local (national) traffic and a high proportion of transit traffic. This creates, in addition to congestion as a result of a crash, heavy structural congestion. As a result, and encouraged by motorcyclists, Luxembourg considers the legalisation of lane filtering on their highways. While aware of the advantages, large concerns were raised in terms of an increased crash risk, dangerous behaviours by road users, and especially the impact of lane filtering on the well-established rescue lane in the country (since both principles make use of the space situated between traffic in the two-leftmost lanes on a highway).

The concept of lane filtering is surrounded by a host of arguments supporting or rejecting the behaviour. Arguments in favour of lane filtering mention the opportunity of motorcyclists to decrease congestion levels, a lower risk to suffer from rear end collisions in congestion, reduce overheating of the rider, lower exposure to emissions, decrease in concentration time as a result of a faster travel time, lower exposure to non-ideal weather conditions (e.g. heat, rain, cold, etc.). Furthermore, it is believed that it creates an opportunity to regulate the behaviour. On the other hand, arguments against lane filtering focus on motorcyclists engaging in more audacious behaviour, a negative impact on the functioning of the rescue lane, unpredictable behaviour of the motorcyclist by other road users, reduced visibility of the motorcyclist, negative impact on the behaviour of other road users due to a feeling of unfairness, and unclarity about the liability.

With regards to the tension between lane filtering and respect for the rescue lane in congestion, two possibly contradicting traditions meet in Luxembourg. On one hand, lane filtering which is routinely conducted (as in Belgium, France, and The Netherlands) while prohibited in Luxembourg. On the other hand, the formation of a rescue lane which has top priority in countries like Germany, Austria, and Luxembourg itself. The question how both concepts can be combined (lane filtering and the formation of a rescue lane) is, however, not only interesting for Luxembourg, but also for other countries that want to combine both principles.

Lane filtering on highways has been legalised in Belgium, The Netherlands and France (experimentally), for which similar motivations can be found, i.e.: Preventing motorcyclists from getting stuck at the end of a traffic jam (which negatively impacts their vulnerability and conspicuity), to increase safety for all road users by providing adequate behavioural rules on lane filtering, to make training possible, and to increase common understanding between road users. These countries apparently believed the behaviour itself would be safe, but that a regulation can help to introduce a commonly accepted correct behaviour.

Luxembourg, by contrast, considers legalising lane filtering, while in Germany it remains strictly prohibited. Germany specifically adds arguments such as: The large occurrence of sudden manoeuvres by car drivers switching lanes, car drivers that get out of their cars in heavy congestion to stretch their legs, and the strict German highway code that considers lane filtering as overtaking on the right or driving with more than two vehicles in one lane. However, it has to be mentioned that these additional German arguments seem to be embedded in a very car-oriented policy and society. In Austria, furthermore, riders are less interested.

In spite of the belief of in an increased crash risk resulting from legalising lane filtering, there seems to be no evidence that lane filtering increases the risk of motorcycle crashes on highways. This can be concluded based on a thorough modelling of Belgian motorcycle highway crashes in this study, combined with a consultation of past studies on motorcycle highway crashes in different countries. Nevertheless, any growth of motorcycling can lead to an increase in motorcycle crashes, as a direct effect of higher exposure (Hakkert & Braimaister, 2002. Additional to lane filtering, other facilitating factors (e.g. allowing motorcycles on bus lanes, reducing taxation, lower parking costs, etc.) can also increase the popularity of motorcycling and increase the number of crashes if no further traffic safety actions are taken. It is thus recommended to increase traffic safety for motorcyclists in general, regardless of the policy decisions.

Furthermore, this study confirms that the positive mobility effects of the legalisation of lane filtering are clearly present. However, the positive effect was found to be marginal. This can be concluded based on the overall monetary and travel time gains over the whole Luxembourgish network (i.e. 1.8 minutes for motorcycles, and 2.1sec for cars when the knock-on effect is ignored for a trip of 20km on the average Luxembourgish highway network). The biggest benefits are for motorcyclists in those contexts where heavy congestion exists for a full 20km trip (i.e. 16 minutes time savings). Based on the network data, these situations were estimated to be rather scarce. While effects are heavily influenced by the number of motorcyclists in the vehicle fleet, with larger benefits when more motorcyclists filter between lanes, the total effects on traffic flow for all road users is rather marginal. Important, these positive effects may be eroded by an increase in other motorised traffic,

i.e. as a result of latent demand, since these shorter travel times can for example convince non-car users to start using the car, or can convince car users to take the highway instead of lower category roads. Also, a negative impact on traffic flow as a result of lane filtering crashes is not suspected, since the crash risk was not found to increase with legalising lane filtering. Nonetheless, Delhaye and Vandael Schreurs (2022) found that motorcycles do show large benefits in terms of mobility, emissions, noise, and space if their modal share can be increased. However, they recommended traffic safety actions since a large increase in crash costs could be observed as a result of the higher share of riders (increased exposure), highlighting again the need for general increased efforts in traffic safety for motorcyclists.

One of the concerns about legalising lane filtering is the fear for more frequent audacious behaviour by motorcyclists. It is feared that motorcyclists would ride at even faster speeds through the congested traffic or would filter between traffic at normal free-flow situations (e.g., weaving between cars that drive 120 km/h already). However, the speed measurements performed in the experimental study in France during the first lane filtering experiment contradict this fear. The share of speeding motorcyclists was reduced by more than 20% and the share of extreme speeding (70 km/h or more) was halved during the three years since lane filtering was legalised. Furthermore, based on expert opinions, a general speed obedience is also estimated to be present in The Netherlands and Belgium (although being it to a lesser extent in Belgium compared to The Netherlands). In addition, full behavioural compliance is estimated to rarely be achieved, since a small but stubborn portion of the population will always neglect existing rules. So, while prejudices might indicate otherwise, objective evidence suggests that the legalisation of lane filtering can help to reduce excessive speeds and other problematic behaviours - among motorcyclists as well as among car drivers. However, specific enforcement and education remains important in order to stimulate the appropriate behaviour, with attention for risk homeostasis (i.e. too much training can also lead to unwanted behaviours due to an overestimation of personal skills).

In relation to the acceptance of lane filtering and the legalisation of lane filtering, opinions varied. While on average, one driver out of five was indifferent, other drivers were equally in favour as opposing a legalisation. On one hand, 46% of the drivers indicated that lane filtering causes problems when legalised and 40% disagree that lane filtering should be legalised in all countries. On the other hand, 32% does not think problems could occur with a legalisation, and 35% believes a legalisation would be a good idea. Nearly half of the drivers were found not to care about the future situation in Luxembourg. Nevertheless, German and Luxembourgish drivers are stricter and show less support for lane filtering compared to drivers from France and Belgium. Probably a different history in relation to lane filtering plays a role in this (legal in Belgium and experimentally legal in France, while strictly forbidden in Germany for a long time and only common practice in Luxembourg). Furthermore, opinions and attitudes of drivers were found to reflect the behaviours and attitudes respective to their country of residence, and not the rules that apply in Luxembourg. Either way, drivers indicated not to perform dangerous behaviours towards lane filtering, regardless of their opinion on the practice.

While support for lane filtering was found to be uneven between the countries, a larger problem was identified concerning little or incorrect knowledge about the topic. 56% (Germany) to around 76% (Belgium, Luxembourg, and France) of the drivers indicated to be familiar with the practice, but only 32% to 57% indicated to know that lane filtering rules exist. Even more worrisome, out of the drivers that indicated to know that rules exist, only half of them could correctly indicate whether lane filtering was legal in their country or not. In fact, only 27% of the drivers in total was fully correct about the legal status, while having mentioned that they knew the rules. The other 73% was incorrect or had to make a guess. The highest portion of correct answers could be observed in Belgium, for which it is assumed that this is a direct effect of the legalisation and clear incorporation in the Belgian highway code. This tends to show that knowledge on lane filtering is a problem, but that legalisation can help improve this.

By definition, the rescue lane leaves room for motorcyclists to pass, and it is mostly acknowledged that riders would not form a major problem for the passing emergency vehicles. They usually ride as fast as the rescue services and even if they must be bypassed, they are small and manoeuvrable enough to timely free the necessary space. However, a code of conduct can be necessary to ensure that motorcyclists keep out of the way of all service vehicles – even when the road is closed. The latter would mean that motorcyclists queue up in line *before* a road closure, to not interfere with the incident. Nevertheless, it has to be kept in mind that complete road closures are a rare occasion in Luxembourg.

The main concern however, is not the mere presence of motorcyclists in the rescue lane, but the fear that their (legally accepted) presence in the rescue lane can influence the proper formation by drivers of four-wheel motor vehicles. It should rather be asked whether making an exception for motorcyclists to enter the

rescue lane would be accepted by other drivers. In fact, this acceptance could be facilitated by explaining that car drivers are not disadvantaged, because they will have to wait in any case, regardless if they let the motorcyclists pass or not. The experiences from The Netherlands, Belgium and France suggest that a legalisation of lane filtering does not meet major resistance from car drivers, but in none of these countries the formation of a rescue lane was at stake at times of this legalisation. Therefore, these best practices from these countries cannot easily be applied in Luxembourg.

On the contrary, this study pointed out that the mere presence of motorcyclists filtering between lanes, does not impact the correct application of the rescue lane. It seems that performing appropriate behaviour towards the rescue lane (i.e. the urge to comply to the regulation), outweighs impulsive actions as a result of the behaviour performed by others. The behaviour in relation to the rescue lane seems mostly influenced by the driver's country of residence. We assume that the longstanding history of the relevant regulation in a country (i.e. the rescue lane concept is longer present in Germany and Luxembourg), results in a higher respect and more appropriate behaviour towards the rescue lane. This again highlights the importance of legislation and knowledge that is an important predictor of adequate behaviour. While lane filtering behaviours were more supported in countries with a clear legalisation of the behaviour, correct rescue lane behaviour was more profound in countries with a longer tradition of the rescue lane concept. The rescue lane thus seems to be a more robust concept which is assumed not to be immediately impacted by a change in legislation in lane filtering.

It needs to be clear that lane filtering should have to be considered as a possibility and not a right. Lane filtering adds to the complexity of driving on highways and expressways where it is practised. In addition, regardless of the legal decision, with its high share of road users from the neighbouring countries, a clear legislation, communication, training, and enforcement are essential to successfully implement lane filtering for motorcyclists with a supporting surface. It is important to provide a guide for adequate and correct behaviour, to avoid lane filtering incidents from happening.

7 Conclusion

It can be concluded that principal concerns raised in terms of an increased crash risk, provoked dangerous behaviours by road users, and the alleged impact on the well-established rescue lane in Luxembourg cannot be considered as decisive arguments for whether or not to legally introduce lane filtering, nor are the proclaimed mobility benefits.

These arguments alone cannot tilt a decision towards introduction of a legal framework in Luxembourg. However, they cannot be considered counterarguments neither, and combined with the benefit of the homogeneity with other surrounding countries, the legalisation of lane filtering could be substantiated.

An introduction of a legal framework could further be defended by the finding that in the absence of negative effects, an increase in appropriate lane filtering behaviour can be expected or induced, knowing that not legalising does not halt the behaviour that already seems to occur. Furthermore, additional arguments such as for example the opportunity for clearer liability rules and a reduced likelihood of exposure to adverse weather conditions, that undeniably affects riders' fitness, further strengthen that position.

An eventual introduction should be combined with appropriate enforcement and educational measures, increased attention to the visibility of riders, and raising mutual understanding between road users.

8 Recommendations

In deciding whether or not to legalise lane filtering, the following recommendations could be followed:

- Considering that Luxembourg is a transit country with both large traffic volumes from abroad, as well as national traffic, legislative choices should be made with caution. It is recommended to create a legislation congruent with other lane filtering countries to avoid behavioural rules that deviate too much between countries. Good practices can be found in Belgium and The Netherlands, which also served as a basis for the French lane filtering conditions.
- A focus on knowledge and training of new motorcyclists is recommended, that can be facilitated through riding courses when applying for a license. This is essential to safely promote lane filtering behaviour with motorcyclists.
- A focus on knowledge and training of new car drivers and other motorised traffic is also recommended, that can be facilitated through driving courses when applying for a license.
- Current motorcycle license holders should be persuaded to follow post-licensing courses that should include knowledge and training on lane filtering behaviour with experienced motorcycle riders. Not only can this help in the context of lane filtering, but also increase motorcycling safety in general.
- Emphasis should be placed on awareness and knowledge about lane filtering for other road users to increase the likelihood of appropriate behaviour.
    - Awareness campaigns can be created (e.g. on billboards next to highways), to warn other road users for the possibility of lane filtering in congestion.
    - Communication about the legislative changes in general media to reach as many drivers as possible.
    - A communication of rules on lane filtering to make legislative changes visible for everyone (e.g. via leaflets, a website, police, etc.)
- Proactively involve rider organisations, car driving organisations, and other transport mode specific organisations (truck, bus, etc.), to increase the coverage of relevant rules for specific transport modes.
- Enforce illegal lane filtering behaviours by motorcyclists where necessary. Couple this enforcement with on-spot education to avoid fining without proposing adequate behaviour. The Netherlands can be considered as a good practice for this approach.
- Target communication to other road users that focusses on the fact that lane filtering by itself has little negative effects for themselves. Waiting times in traffic won't increase, while the behaviour (if correctly performed) shouldn't be considered as unsafe. Focus on the avoidance of sudden manoeuvres, using the indicators, and avoiding distractive elements that are not only obligatory behaviours by law but also safer for motorcyclists.
- Increase general knowledge on the rescue lane concept for all foreign drivers, while emphasising focus on drivers coming from France and Belgium, that were found to apply the rescue lane concept less strictly. This can be done by specific campaigns focussing on the highways where these road users are most likely to drive (i.e. A3/A4 and A6 respectively)
- Include information on lane filtering in future rescue lane communications. Consider adapting the vertical signalisation or banners with the practice of the rescue lane, including a motorcyclist in the picture.
- Explicitly mention that the rescue lane must be prioritised over lane filtering when applicable, where motorcyclists should avoid hindering rescue services (or signalling vehicles).
- Provide best practices or a code of conduct to motorcyclists and car/truck drivers on how to behave when encountering a roadblock in case of a serious crash.
- Clearly define rules for each road users, to avoid confusion, and focus on mutual understanding and courtesy between road users. Don't target one transport mode only.
- Increase traffic safety for motorcyclists in general, regardless of the policy decisions made in the context of motorcycling.
- Be conscious that audacious and completely unsafe behaviours can be performed by all road users. Hence, don't target one transport mode only. There will always be a minor group of road users that completely ignore set up rules, regardless the legal status of lane filtering.

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Annexes

I. Questionnaire

INTRODUCTION

Vias institute is carrying out a research project for the Luxembourg Ministry of Mobility and Transport to investigate the respect of the rescue lane in different countries.

Your experience and/or your honest opinion is important for this study. Your answers can never be traced back to you and will not be used to fine or prosecute.

The completion time of this questionnaire is estimated to be maximally 15min.

Thank you in advance for your time and care in answering!

GDPR

Information concerning the adoption of the GDPR can be found here:

Page break

SOCIO-DEMO

First, we would like to get a bit more information about you, before continuing the questionnaire.

1. **What is your native language?**
   a) Dutch
   b) French
   c) German
   d) Luxembourgish
   e) Other

Force answer
Only 1 answer possible
Continue questionnaire in native language
Page break

2. **Where do you currently live? (main residence)**

France	Germany
a) Auvergne-Rhône-Alpes	n) Baden-Württemberg
b) Bourgogne-Franche-Comté	o) Bayern
c) Bretagne	p) Berlin
d) Centre-Val de Loire	q) Brandenburg
e) Corse	r) Bremen
f) Grand Est	s) Hamburg
g) Hauts-de-France	t) Hessen
h) Île-de-France	u) Mecklenburg-Vorpommern
i) Normandie	v) Niedersachsen
j) Nouvelle-Aquitaine	w) Nordrhein-Westfalen
k) Occitanie	x) Rheinland-Pfalz
l) Pays de la Loire	y) Saarland
m) Provence-Alpes-Côte d'Azur	z) Sachsen-Anhalt
	aa) Sachsen
	bb) Schleswig-Holstein
	cc) Thüringen

Belgium	Luxembourg
dd) Antwerpen	oo) Capellen (Capellen)
ee) Limburg	pp) Clervaux (Klierf)
ff) Oost-Vlaanderen	qq) Diekirch (Dikrech)
gg) Vlaams-Brabant	rr) Echternach (Iechternach)
hh) West-Vlaanderen	ss) Esch-sur-Alzette (Esch-Uelzecht)
ii) Brussels-Hoofdstedelijk Gewest	tt) Grevenmacher (Gréiwemaacher)
jj) Henegouwen	uu) Luxemburg (Lëtzebuerg)
kk) Luik	vv) Mersch (Miersch)
ll) Luxemburg	ww) Redange (Réiden)
mm) Namen	xx) Remich (Réimech)
nn) Waals-Brabant	yy) Vianden (Veianen)
	zz) Wiltz (Wolz)

Only continue for France if f) is selected / Only continue for Germany if x) or y) is selected
Force answer
Only 1 answer possible
Page break

3. What is your gender?

a) Male
b) Female
c) Other / Prefer not to respond

Force answer
Only 1 answer possible

4. In which year were you born?

.....

Force answer
Limit answer between 17 and 99

5. Are you currently holding any type of driver license?

a) Yes
b) Yes, Provisional
c) No

Force answer
Only 1 answer possible
If b) or c) selected → exclude
Page break

6. How often do you use (or did you use) <u>as a driver</u> the following transport modes?

	Car / Van	Bus / Truck	Motorcycle
I drive/ride it frequently	a)	a)	a)
Is drive/ride it occasionally	b)	b)	b)
I drove/rode it frequently in the past but not anymore	c)	c)	c)
I drove/rode it occasionally in the past but not anymore	d)	d)	d)
I never drove/rode it	e)	e)	e)

Force answer
Per column only 1 answer possible
If 'Never' selected on all 3 colums → exclude
Page break

7. Do you drive in Luxembourg (country)?

a) Yes, frequently (couple of times per month or more frequently)
b) Yes, sometimes (couple of times per year)
c) Yes, I drove there once or twice
d) No, I have never driven in the country Luxembourg before

Force answer
Only 1 answer possible
If d) selected → Exclude
Do not ask Q7 if options under 'Luxembourg' were selected in Q2
Page break

RESCUE LANE

In this questionnaire, we will be focussing on the rescue lane.

What is a rescue lane?

A rescue lane is formed in slow or stopped traffic on a highway between the two leftmost lanes, often as a result of an accident. This leaves room for an emergency vehicle or signalling vehicle to pass through as shown in the picture[7].

Nowadays, more and more countries require drivers to create a rescue lane whenever a traffic jam is forming.

8. After reading the information about the rescue lane, which option fits best?

a) I was already (somewhat) familiar with the concept
b) It is completely new to me

Force answer
Only 1 answer possible
Page break

9. When you are stuck in traffic, how often do you behave in the following way?

	Never	Sometimes	Often	Always
I move immediately to the side to form a rescue lane.	a)	b)	c)	d)
I drive more to the middle to see what's going on.	a)	b)	c)	d)
When other vehicles leave enough space in the rescue lane, I am tempted to use it to get ahead more quickly.	a)	b)	c)	d)
I only form a rescue lane when I hear the rescue services or police approaching from behind.	a)	b)	c)	d)
I always leave space, even if there is no rescue vehicle approaching from behind.	a)	b)	c)	d)
When other vehicles leave enough space in the rescue lane, I attempt to use it to get ahead more quickly.	a)	b)	c)	d)
I only leave space for the rescue lane if other drivers do so as well.	a)	b)	c)	d)
I forget to form a rescue lane	a)	b)	c)	d)

Force answer
Per row only 1 answer possible
Page break

[7] Source picture : https://de.wikipedia.org/wiki/Rettungsgasse

10. In your opinion, which road users should be allowed to make use of the rescue lane? (which road users you believe should be allowed, regardless being legal or not at this moment)

	Absolutely	Probably	Not sure	Probably not	Absolutely not
Ambulance	a)	b)	c)	d)	e)
Police (any vehicle)	a)	b)	c)	d)	e)
Fire brigade (any vehicle)	a)	b)	c)	d)	e)
Maintenance/signalling vehicles (often equipped with an orange flashing light)	a)	b)	c)	d)	e)
Motorcyclists	a)	b)	c)	d)	e)
Car drivers in case of emergency (e.g. with a sick passenger, injured person, etc.)	a)	b)	c)	d)	e)

Force answer
Per row only 1 answer possible
Page break

SPECIFIC SITUATIONS IN LUXEMBOURG

In this part of the questionnaire we will specifically focus on some situations **in the country Luxembourg**, in case of a traffic jam.

In order to fill in this part of the questionnaire, you would have to **imagine yourself that you would be driving on a highway in Luxembourg**. Some situations will be shown to you, for which you will have to indicate how you would behave in that situation.

11. You get stuck with your car in a traffic jam in Luxembourg, and you notice that the other drivers are not really forming a rescue lane.

With motorcycle riders

With motorcycle riders

What would you do?

	Not likely at all	Not likely	Likely	Very likely	I don't know
I move to the outer side to form a rescue lane as required and hope that other drivers will follow my example.	a)	b)	c)	d)	e)
I would drive normally in the middle of my lane.	a)	b)	c)	d)	e)
I drive to the inner side of my lane to have a better view on what's going on.	a)	b)	c)	d)	e)

Force answer
Per row only 1 answer possible
Page break

12. Imagine that you are driving a car on the left lane on the highway in Luxembourg and get caught up in a traffic jam. A rescue lane has already been formed, but after 20min, traffic is still moving slowly.

With motorcycle rider

With motorcycle rider

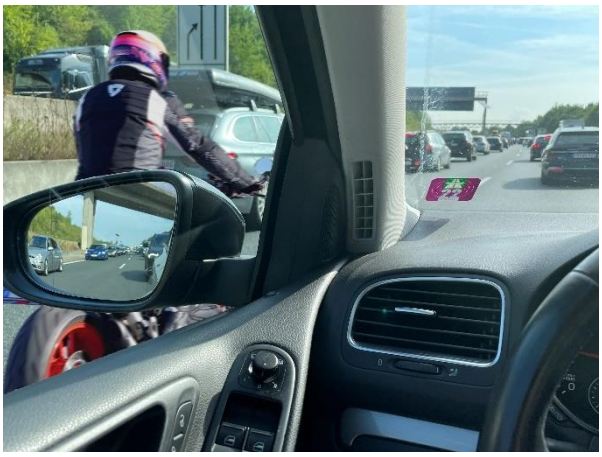
What would you do?

	Not likely at all	Not likely	Likely	Very likely	I don't know
I stay to the side of the rescue lane as required	a)	b)	c)	d)	e)
I move a bit away from the side in order to be able step outside my vehicle to stretch my legs	a)	b)	c)	d)	e)
I drive to the middle as much as possible to see if anything is changing .	a)	b)	c)	d)	e)

Force answer
Per row only 1 answer possible
Page break

13. Now, imagine yourself that you are driving a car on the right lane on the highway in Luxembourg. Suddenly you get caught up in a traffic jam. The exit you want to take is only 500m away, but there is no room to pass vehicles on the right. A rescue lane is formed and after waiting for 20 minutes, not a single car has moved for even 1 metre.

With motorcycle rider



With motorcycle rider

What would you do?

	Not likely at all	Not likely	Likely	Very likely	I don't know
Stay where I am right now at the far right in the rescue lane even if it takes another 20min.	a)	b)	c)	d)	e)
Move to the left to see if I can already spot my exit and understand what is going on.	a)	b)	c)	d)	e)
Make use of the rescue lane since it is only a very short distance to my next exit.	a)	b)	c)	d)	e)

Force answer
Per row only 1 answer possible
Page break

14. Imagine yourself, you have an important appointment that you absolutely cannot miss. You left your home on time and took the highway with your car. However, you suddenly get caught up in a traffic jam, and your GPS/smartphone indicates that you will now be 30min late due to the traffic jam.

With motorcycle rider

With motorcycle rider

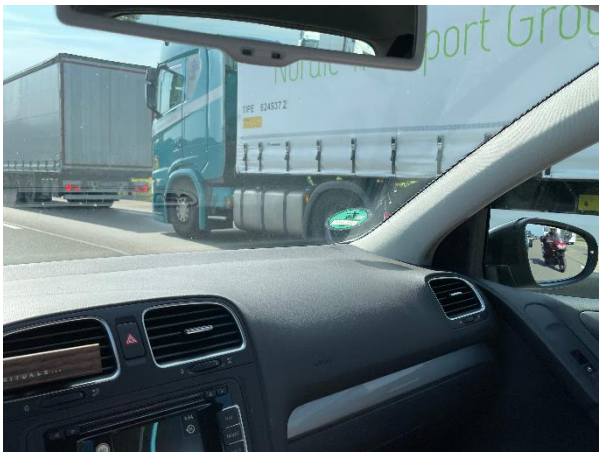
What would you do?

	Not likely at all	Not likely	Likely	Very likely	I don't know
I immediately move aside to form a rescue lane as required even if that means I will miss my important appointment.	a)	b)	c)	d)	e)
I move to the middle to check if I can spot an exit that I can take in the hope to still reach my important appointment on time.	a)	b)	c)	d)	e)
I make use of the rescue lane until the next exit, because I cannot miss my important appointment.	a)	b)	c)	d)	e)

Force answer
Per row only 1 answer possible
Page break

15. Imagine that you are on the highway in Luxembourg in the left lane while getting caught up in a traffic jam. Traffic is moving slowly, but a rescue lane is being formed.

With motorcycle rider



With motorcycle rider

What would you do?

	Not likely at all	Not likely	Likely	Very likely	I don't know
Form a rescue lane at the very left as required.	a)	b)	c)	d)	e)
I stay where I am in my lane without moving to the right side to see if nobody else will make use of the rescue lane, except emergency vehicles.	a)	b)	c)	d)	e)
Block all the available space of the rescue lane to let no one pass except emergency services and only move away when I see an emergency vehicle.	a)	b)	c)	d)	e)

Force answer
Per row only 1 answer possible
Page break

16. Lastly, imagine that you are on the highway in Luxembourg caught up in a traffic jam. You have been standing still for a while and an ambulance is passing.[8]

With motorcycle riders

With motorcycle riders

[8] Source picture : https://www.oeamtc.at/presse/oeamtc-rettungsgasse-in-europa-strafen-bei-missachtung-teils-verschaerft-36886060

What would you do?

	Not likely at all	Not likely	Likely	Very likely	I don't know
I stay at the outer side to keep the rescue lane open.	a)	b)	c)	d)	e)
I drive back to the middle of my lane to see if nobody else will make use of the rescue lane, except emergency vehicles.	a)	b)	c)	d)	e)
I block all the available space of the rescue lane to let no one pass except emergency services and only move away when I see an emergency vehicle.	a)	b)	c)	d)	e)

Force answer
Per row only 1 answer possible
Page break

GENERAL FOCUS ON LANE FILTERING

In the final part of the questionnaire we would like to focus on motorcyclists that filter between lanes on highway in a traffic jam. In some countries, it is legal, while in other countries it is not. Because of this, we would like to gather your opinions on **lane filtering for motorcycles on highways in <u>your country</u>**.

<u>A motorcyclist **is** lane filtering if</u>

- **traffic is moving slow or has come to a full stop** in a cue or traffic jam.
- he/she **rides between two lanes of vehicles** at a **slow/adapted speed**.
- he/she rides **between the two most left lanes.**

<u>Lane filtering **IS NOT**</u>

- riding at very high speeds in between traffic (= weaving)
- passing on the breakdown lane
- passing on the left side of the most left lane

17. After reading the information about lane filtering, which option fits best?

c) I was already (somewhat) familiar with the concept
d) It is completely new to me

Force answer
Only 1 answer possible

18. Did you know that some rules applied to lane filtering?

a) Yes, I know that some rules apply to this practice
b) No, I didn't knew that rules applied to this practice

Force answer
Only 1 answer possible
Page break

19. How common is lane filtering:

	In your country	In Luxembourg
It happens all the time / a lot of riders perform it	a)	a)
It happens sometimes / some riders perform it	b)	b)
It is quite rare / seldomly a rider performs it	c)	c)
It is not performed at all / no rider performs it	d)	d)
I don't know	e)	e)

Force answer
Only 1 answer possible per column
Do not ask column 2 if options under 'Luxembourg' were selected in Q2

20. Do you know if lane filtering is legal or not?

	I know it is illegal	I think it is illegal	I think it is legal	I know it is legal	I don't know
In your country	a)	b)	c)	d)	e)
In Luxembourg	a)	b)	c)	d)	e)

#Force answer
#Only 1 answer possible per row
#Do not ask row 2 if options under 'Luxembourg' were selected in Q2
Page break

21. To what extent do you agree with the following statements?

	I fully disagree	I disagree	I agree	I fully agree	No opinion
Lane filtering and riding a motorcycle go hand in hand	a)	b)	c)	d)	e)
Lane filtering is asocial	a)	b)	c)	d)	e)
Lane filtering improves traffic flow for everyone	a)	b)	c)	d)	e)
Lane filtering is a cause for accidents	a)	b)	c)	d)	e)
Lane filtering contributes to less air pollution	a)	b)	c)	d)	e)
Motorcyclists who filter between traffic are not respecting the rescue lane	a)	b)	c)	d)	e)
Only motorcyclists benefit from lane filtering	a)	b)	c)	d)	e)
Lane filtering is safe	a)	b)	c)	d)	e)
Motorcyclists tend to ride respectful when they filter between lanes	a)	b)	c)	d)	e)
Indicate the option "I fully agree"	a)	b)	c)	d)	e)
Lane filtering is unfair to other drivers stuck in traffic	a)	b)	c)	d)	e)
I'm against lane filtering	a)	b)	c)	d)	e)
It is dangerous when a car and motorcycle are (nearly) on the same lane.	a)	b)	c)	d)	e)
To me, lane filtering is the same as overtaking on the right and should therefore be forbidden/remain forbidden	a)	b)	c	d)	e)

Force answer
Only 1 answer possible per row
Page break

22. In some countries, lane filtering for motorcycles is legal, while in other countries, it isn't To what extend do you agree with the following statements?

	I fully disagree	I disagree	No opinion	I agree	I fully agree
Lane filtering for motorcyclists should be legal in all countries	a)	b)	c)	d)	e)
Lane filtering for motorcyclists causes problems when it is legalised	a)	b)	c)	d)	e)

Force answer
Only 1 answer possible per row

23. Please explain why you gave this answer

.....

Do not force answer
Page break

24. Which of the following actions do you perform when you are stuck in traffic as a car, bus or truck driver?

	Never	Sometimes	Often	Always
I check my rear-view mirrors (in-vehicle or side mirrors)	a)	b)	c)	d)
I try to check my blind spots	a)	b)	c)	d)
I use my indicator before changing lanes	a)	b)	c)	d)
I avoid sudden manoeuvres	a)	b)	c)	d)
I move aside to let motorcyclists pass who are legally filtering between the lanes	a)	b)	c)	d)
I pay attention to road users in my vicinity	a)	b)	c)	d)
I avoid anything that can distract me (GPS, phone, etc.)	a)	b)	c)	d)
I move aside to create an rescue lane, even if there is no rescue vehicle coming	a)	b)	c)	d)
I strictly follow the speed limit (e.g. I never exceed the speed limit, not even if it is temporary)	a)	b)	c)	d)

Force answer
Only 1 answer possible per row
Page break

25. Which of the following actions do you perform when you are stuck in traffic in relation to lane filtering specifically as a car, bus or truck driver?

	Never	Sometimes	Often	Always
I choose the lane where I am least likely to encounter lane filtering motorcyclists (e.g. the most right lane)	a)	b)	c)	d)
I prefer not to change lanes (e.g. I stay on the right lane, even if it seems it is moving slower)	a)	b)	c)	d)
I avoid areas where lane filtering is being performed (e.g. I take another route because on a specific stretch of highway motorcyclists always filter between lanes)	a)	b)	c)	d)
I move aside to prevent a motorcyclist to filter between the lane, thereby blocking their passage	a)	b)	c)	d)

Force answer
Only 1 answer possible per row
Page break

26. **When we specifically talk about lane filtering in Luxembourg (which is currently illegal), to which extend do you agree with the following statements?**

	I fully disagree	I disagree	I agree	I fully agree	No opinion
Lane filtering could cause problems in Luxembourg when it is legalised	a)	b)	c)	d)	e)
It would be a good idea if the Luxembourg government would legalise lane filtering	a)	b)	c)	d)	e)
I don't care what the situation is or will be in Luxembourg	a)	b)	c)	d)	e)

Force answer
Only 1 answer possible per row
Page break

27. Do you have any comments or feedback?

.....

End questionnaire

II. Regression analysis questionnaire: model specification

Stated behaviours of drivers in relation to their behaviour in the rescue lane were questioned. This was done through a series of statements dealing with rescue lane behavior, where drivers had to indicate the likelihood of performing a specific behaviour, ranging from "Not at all" and "Unlikely" to "Likely" and "Very Likely". This answering scale can be seen as a natural order. To be able to determine an effect of motorcyclists, pictures were shown whether or not with a motorcyclist present in the rescue lane.

To investigate the possible differences in behaviour of car drivers, as a result of the shown pictures with or without motorcyclists present in the rescue lane, a series of ordered logit fixed effects models were used. These ordered logit models were chosen instead of Ordinary Least Squares (OLS) regressions given that the dependent variables are ordinal in nature.

A fixed effects approach was applied because the dataset includes multiple countries (i.e. Belgium, France, Germany and Luxembourg), implying that individuals are nested within countries, resulting in the violation of the assumption of independency of observations. Furthermore, a country fixed effects approach was preferred above a multilevel approach, since only four countries were present in the dataset. This is generally considered too low for multilevel modeling (for a more elaborate discussion on this topic, see for instance Bryan & Jenkins, 2016, among others). In such a context, a fixed effects approach is preferred, where this design avoids country-level omitted variable bias through controlling for country-level heterogeneity by making use of country dummy variables (Allison, 2009, p. 14).

The models are listed below, and are structured according to the type of behavior of interest; i.e. opening of rescue lane (Table 1; V011-V012[9]), making use of the rescue lane (Table 2; V013-V014) and blocking of the rescue lane (Table 3; V015-V016). Apart from a picture dummy, which is the independent variable of interest, the models also include various demographic (age, gender) and behavioral (driving with bus/motorbike; driving in Luxembourg) controls, as well as country dummies, all believed to be associated with the dependent variables. The various models were estimated in Stata13. For easier model comparison, (proportional) odds ratios are shown, and not ordered logit coefficients. Multicollinearity between variables was tested, where variance inflation factors for the independent variables were all well below 10, which is the accepted benchmark to test multicollinearity. Missing values were also limited, and mainly the result from people answering "don't know" on the dependent variables.

[9] V011 and V012 refer, respectively, to the questions in annex I, as do V013, V014, V015, and V016

Table 1. Explaining Opening of Rescue Lane Behavior

VARIABLES	V011_1	V011_2	V011_3	V012_1	V012_2	V012_3
Picture1 (0 = no motorbike)	0.893	1.178**	1.040			
	(0.073)	(0.083)	(0.081)			
Picture2 (0 = no motorbike)				0.854*	0.956	1.030
				(0.078)	(0.082)	(0.080)
Country (ref: Belgium)						
Germany	3.802***	0.252***	0.396***	1.315**	0.874	0.460***
	(0.489)	(0.025)	(0.044)	(0.167)	(0.104)	(0.051)
France	0.748***	1.743***	1.090	0.893	0.669***	0.712***
	(0.083)	(0.192)	(0.120)	(0.114)	(0.094)	(0.084)
Luxembourg	2.282***	0.343***	0.238***	1.832***	0.441***	0.388***
	(0.494)	(0.070)	(0.054)	(0.406)	(0.105)	(0.088)
Gender (ref: Male)	0.904	1.087	0.819**	0.925	0.832**	0.931
	(0.077)	(0.079)	(0.066)	(0.087)	(0.074)	(0.074)
Age	1.012***	0.987***	0.990***	1.011***	0.982***	0.992***
	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Driving a Bus/Truck (ref: Never)						
Frequently	1.101	0.822*	1.237*	0.859	1.243*	1.240*
	(0.152)	(0.092)	(0.150)	(0.122)	(0.157)	(0.151)
Only in the past	1.151	0.875	1.168	0.910	1.121	1.044
	(0.125)	(0.080)	(0.125)	(0.115)	(0.128)	(0.109)
Driving a motorcycle (ref: Never)						
Frequently	1.116	0.935	1.103	0.792	1.395**	1.299*
	(0.158)	(0.111)	(0.146)	(0.117)	(0.192)	(0.177)
Only in the past	1.083	0.923	0.858	1.057	1.016	1.129
	(0.132)	(0.093)	(0.096)	(0.140)	(0.121)	(0.123)
Driving in Luxembourg (ref: Frequently)						
Sometimes	1.062	0.819	0.689*	0.967	0.698*	0.841
	(0.211)	(0.158)	(0.144)	(0.197)	(0.151)	(0.177)
Only once or twice	1.007	0.996	0.708*	1.073	0.656**	1.016
	(0.199)	(0.189)	(0.145)	(0.214)	(0.139)	(0.207)
Observations	3,026	3,016	3,019	3,040	3,046	3,059

Note: Coefficients are **Odds Ratios.** The values of the cut points to ordered logit regression are not shown.
Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 2. Explaining Making Use of Rescue Lane Behavior

VARIABLES	V013_1	V013_2	V013_3	V014_1	V014_2	V014_3
picture3 (0 = no motorbike)	0.908	0.959	1.098			
	(0.072)	(0.069)	(0.089)			
picture4 (0 = no motorbike)				1.060	1.066	1.001
				(0.085)	(0.077)	(0.085)
Country (ref: Belgium)						
Germany	1.786***	0.379***	0.415***	3.487***	0.373***	0.493***
	(0.206)	(0.038)	(0.049)	(0.457)	(0.037)	(0.061)
France	0.992	0.742***	0.881	0.859	0.918	1.043
	(0.117)	(0.083)	(0.106)	(0.095)	(0.104)	(0.130)
Luxembourg	1.227	0.544***	0.442***	1.694**	0.501***	0.475***
	(0.262)	(0.122)	(0.100)	(0.362)	(0.103)	(0.110)
Gender (ref: Male)	0.935	1.097	1.034	0.946	0.990	0.826**
	(0.078)	(0.082)	(0.086)	(0.079)	(0.074)	(0.072)
Age	1.009***	0.990***	0.994**	1.013***	0.991***	0.983***
	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Driving bus/Truck (ref: Never)						
Frequently	0.958	1.128	1.130	1.006	0.938	1.324**
	(0.126)	(0.131)	(0.146)	(0.131)	(0.107)	(0.171)
Only in the past	0.962	1.119	1.049	1.096	0.944	1.214*
	(0.107)	(0.108)	(0.114)	(0.123)	(0.091)	(0.137)
Driving a motorcycle (ref: Never)						
Frequently	0.704***	1.227	1.562***	0.879	1.206	1.152
	(0.094)	(0.158)	(0.202)	(0.123)	(0.157)	(0.162)
Only in the past	0.959	1.075	1.156	0.899	1.113	1.249*
	(0.112)	(0.111)	(0.136)	(0.105)	(0.108)	(0.144)
Driving in Luxembourg (ref: Frequently)						
Sometimes	0.837	1.111	0.849	0.971	0.984	0.762
	(0.169)	(0.232)	(0.176)	(0.196)	(0.193)	(0.162)
Only once or twice	0.788	1.244	0.841	1.080	1.025	0.769
	(0.157)	(0.256)	(0.171)	(0.215)	(0.197)	(0.160)
Observations	3,037	3,029	3,022	3,008	3,008	3,028

Note: Coefficients are **Odds Ratios.** The values of the cut points to ordered logit regression are not shown.
Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 3. Explaining Blocking of Rescue Lane Behavior

VARIABLES	V015_1	V015_2	V015_3	V016_1	V016_2	V016_3
picture5 (0 = no motorbike)	1.122	1.003	1.005			
	(0.100)	(0.069)	(0.082)			
picture6 (0 = no motorbike)				0.915	1.002	0.973
				(0.091)	(0.080)	(0.081)
Country (Ref: Belgium)						
Germany	3.098***	0.597***	0.277***	2.751***	0.277***	0.254***
	(0.469)	(0.060)	(0.037)	(0.458)	(0.036)	(0.036)
France	0.766**	1.183*	1.343***	0.894	1.324**	1.423***
	(0.090)	(0.110)	(0.154)	(0.118)	(0.151)	(0.165)
Luxembourg	1.391	1.132	0.390***	1.933***	0.331***	0.356***
	(0.307)	(0.203)	(0.084)	(0.455)	(0.071)	(0.080)
Gender (ref: Male)	0.874	0.986	0.972	1.070	1.013	1.125
	(0.080)	(0.071)	(0.083)	(0.109)	(0.083)	(0.098)
Age	1.014***	0.998	0.980***	1.016***	0.989***	0.987***
	(0.003)	(0.002)	(0.003)	(0.004)	(0.003)	(0.003)
Driving a Bus/Truck (ref: Never)						
Frequently	0.840	1.374***	1.159	0.903	1.153	1.169
	(0.118)	(0.154)	(0.150)	(0.136)	(0.144)	(0.159)
Only in the past	0.947	1.163	1.062	1.220	1.006	1.063
	(0.121)	(0.109)	(0.121)	(0.182)	(0.111)	(0.120)
Driving a motorcycle (ref: Never)						
Frequently	0.781*	1.079	1.278*	0.726**	1.259*	1.373**
	(0.116)	(0.125)	(0.176)	(0.114)	(0.171)	(0.195)
Only in the past	0.999	0.964	0.895	0.997	1.047	0.826*
	(0.130)	(0.092)	(0.105)	(0.144)	(0.117)	(0.096)
Driving in Luxembourg (ref: Frequently)						
Sometimes	1.031	1.240	0.790	1.129	0.698*	0.720
	(0.209)	(0.206)	(0.161)	(0.248)	(0.139)	(0.153)
Only once or twice	1.060	1.136	0.758	1.169	0.662**	0.658**
	(0.210)	(0.186)	(0.149)	(0.252)	(0.128)	(0.135)
Observations	3,030	2,981	3,022	3,049	3,026	3,027

Note: Coefficients are **Odds Ratios.** The values of the cut points to ordered logit regression are not shown.
Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

III. Mobility effects of lane filtering in Luxembourg