Vehicle technologies and standards

A preliminary assessment for prioritisation

NZIER report to the Ministry of Transport

October 2018

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NZIER was established in 1958.

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Key points

Objectives and scope

NZIER was asked by the Ministry of Transport (the Ministry) to conduct an initial assessment of the benefits and costs of six vehicle technologies or standards (the options).

The options we were asked to assess were:

- Electronic stability control (ESC) for heavy vehicles
- Anti-lock braking systems (ABS) for heavy vehicles and motorcycles
- Autonomous emergency braking (AEB) for all vehicles except motorcycles
- Side protection standards for light vehicles
- Side airbags for light vehicles
- Underrun protection for heavy vehicles.

Our assessment considered the following questions:

- Which options are likely to have benefits that exceed the costs?
- Which options should be prioritised for further assessment?
- What is the likelihood that the options will enter the vehicle fleet without intervention?

The scope of the research was limited to a preliminary assessment of the benefits and costs. The purpose of the research was to inform decision-making about prioritising potential future research.

The research was not intended to directly lead to regulation and the results should not be treated as robust enough to move directly to regulatory changes.

We identified significant information gaps in our research, which means that the results are quite uncertain in several cases. Gathering more evidence to fill the information gaps is the natural next step and is necessary for a detailed assessment of the options.

Work is needed to fill information gaps and reduce uncertainty

Uncertainty about the level of fitment in the existing vehicle fleet was a factor for all options. New Zealand is not alone here. Discussion about the lack of data on fitment rates is common in the international literature.

Gathering better information about fitment rates in the existing fleet and vehicles entering the fleet for all technologies would strengthen the road safety evidence base beyond the specific aims of this research.

Consultation with industry will be required and is key to building the evidence base.

The analysis of the benefits of underrun protection was particularly uncertain because underrun injuries are not captured in the crash analysis statistics.

Results of the assessment of the options

A summary of the benefit-cost ratios (BCRs) estimated in the assessment is shown in Table 1. A BCR greater than one indicates the initial assessment suggests the benefits are likely to exceed the costs.

We recommend the green options for prioritisation. The amber options need more data on fitment or injuries. We do not recommend the red options be prioritised.

Table 1 Summary of the assessment of potential benefits and costs

Option	Low BCR	Medium BCR	High BCR
ESC[1] for heavy vehicles entering the fleet	0.9	1.0	1.3
ESC[1] for all heavy vehicles	0.3	0.4	0.6
ABS[2] for motorcycles	3.0	6.1	12.2
ABS for heavy vehicles	0.3	0.5	1.4
Low speed AEB[3] for all vehicles excluding motorcycles	0.2	0.6	0.8
Side impact (airbags) for light vehicles	0.07	0.1	0.4
Underrun protection for heavy vehicles	0.7	1.0	2.0

Notes: 1 Electronic stability control 2. Anti-lock braking systems 3. Autonomous emergency braking

Source: NZIER

The recommendations and key findings for each option are summarised in Table 2.

Table 2 Summary of the results and recommendations

Option	Description	Results	Recommendations
Electronic stability control (ESC) for heavy vehicles. ESC is designed to prevent loss-of-control crashes.	Two policy options were considered: - ESC for all heavy vehicles - ESC for heavy vehicles entering the fleet only.	The benefits of fitting to existing heavy vehicles exceeds the costs. Retrofitting the ESC to all vehicles in the fleet will cost around 3 times the cost of the factory fitted option. The benefits of retrofitting were less than the costs.	We recommend ESC for heavy vehicles entering the fleet should be prioritised for further consideration. We do not recommend prioritising ESC for heavy vehicles already in the fleet.
Anti-lock braking systems (ABS) for heavy vehicles and motorcycles. ABS is designed to avoid a loss of traction which can result in crashes and injuries.	Two policy options were considered: - ABS for motorcycles entering the fleet - ABS for heavy vehicles entering the fleet only.	The benefits of ABS for motorcycles entering the fleet are likely to be around 6 times higher than the costs. The results for ABS on heavy vehicles are mixed. The benefits might exceed the costs, but the results were sensitive to the costs and they vary by truck size and configuration.	We recommend prioritising investigation of mandatory ABS for motorcycles entering the fleet. We recommend gathering more disaggregated data on the cost of ABS for heavy vehicles.
Autonomous emergency braking (AEB) for all vehicles except motorcycles. There are three categories of AEB technologies: low speed, high speed and AEB designed for pedestrian and cycle safety.	The assessment investigated low speed AEB, because they had recently become included as standard in cars offered by some manufacturers.	The benefits did not exceed the costs in this assessment.	The recommendation for low speed AEB is to maintain a watching brief, rather than doing further analysis at this stage. Gathering more information on the rate of fitment in new imports will improve the wider evidence base for transport research.
Side curtain airbags and side protection standards for light vehicles. Side curtain airbags are designed to reduce the risk and severity of injuries to the head and body because of a side impact collision.	There is an overlap between the injuries targeted by airbags and side protection standards. They were considered together in the assessment.	Neither option had benefits that exceeded the costs.	Neither technology should be prioritised for further consideration at this time.
Underrun protection for heavy vehicles. Underrun protection is intended to address the height mismatch between heavy vehicles and other road users.	There are significant information gaps in the assessment of this technology. For example, there are no official statistics on the number and severity of underrun crashes or the fitment rate of underrun protection in the existing fleet.	The results were sensitive to the assumptions. The benefits could potentially exceed the costs.	We recommend that more data on is gathered before this option can be further assessed.

Source: NZIER

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1. Objectives and scope

NZIER was asked by the Ministry of Transport (the Ministry) to conduct an initial assessment of the benefits and costs of six vehicle technologies or standards ("the options"). Our assessment considered the following questions:

1. Which options are likely to have benefits that exceed the costs?
2. Which options should be prioritised for further assessment?
3. What is the likelihood that the options will enter the vehicle fleet without intervention?

The scope of the assessment was limited to a preliminary assessment of the benefits and costs of each option. A detailed assessment of the benefits and costs was out of scope.

Our assessment is intended to inform decisions about further investigation, which could include a detailed cost-benefit analysis. The assessment was not intended to lead to direct regulatory changes.

Research approach

Our approach had three key components:

1. Literature review to gather information on:
   - the effectiveness of the options for reducing injuries
   - the costs of the options
   - global vehicle market trends.
2. Safety analysis to establish an evidence-based view of the potential benefits of the options.
3. Analysis of international and domestic vehicle market trends.

We applied a consistent methodology for all the options. For each option we:

- Identified which crash types would be affected by the option being assessed.
- Reviewed the literature to identify the potential reduction in injury rates associated with the option.
- Applied the injury rate reduction from the literature to the relevant crash data in New Zealand for the period from 2014 to 2016 and estimate the annual average reduction in the social cost of injuries for the option.
- Identified the number of vehicles that will be impacted by the option between 2019 and 2038.
- Estimated the rate of fitment in the baseline for 2019 to 2038 based on:
  - the estimated current rate of fitment in the fleet
  - separate estimates of the fitment rate for new and used vehicles entering the fleet
  - the change in the rate of fitment based on the growth and turnover in the vehicle fleet.

- Estimated the benefits and costs associated with the baseline trend without intervention.
- Modelled the benefits and costs of a policy intervention based on a change in the fitment rate for vehicles entering the fleet.
- Modelled the benefits and costs of a policy intervention on the fitment rate for existing fleet if there is the option to retrofit the option
- Compared the benefits and costs in the intervention scenarios to those estimated for the baseline to establish whether the intervention was likely to generate benefits that exceed the costs.
- Reported results in 2017 prices.

We also used the following assumptions and parameters for each option assessment:

- The evaluation period was 2019 to 2038.
- The intervention comes into effect in 2021.
- A 6% discount rate
- 100% compliance.
- The proportion of the vehicle fleet that leaves the fleet annually is based on the median proportion between 2012 and 2016:
  - 7% for light passenger vehicles
  - 8% for light commercial vehicles
  - 5% for motorcycles
  - 4% for heavy vehicles.

2. The options at a glance

We summarise below the six vehicle technologies or standards we were asked to investigate.

Electronic stability control (ESC) for heavy vehicles

Electronic stability control is designed to prevent loss-of-control crashes. It works by the vehicle detecting a loss of control or traction on any wheel and applying braking or power automatically to maintain the vehicle's stability and direction of travel. In the case of heavy vehicles, ESC reduces the risk of roll-over and jack-knife incidents.

Anti-lock braking systems (ABS) for heavy vehicles and motorcycles

ABS is designed to avoid a loss of traction which can result in crashes and injuries. ABS give drivers confidence to fully apply braking when they otherwise might be tentative due to the risk of lock-up. This can shorten the stopping distance.

ABS also allow drivers to steer the vehicle under heavy braking, which can help them avoid objects and/or reduce the severity of the collision. ABS can contribute to a reduction in the incidence or severity of all types of crashes, but it is particularly effective in head-on and nose-to-tail crashes.

Autonomous emergency braking (AEB) for all vehicles except motorcycles

AEB is designed to prevent frontal collisions and reduce the number and/or severity of injuries. The technologies use radar or cameras to perceive hazards. The hazards can include roadside objects, vehicles, cyclists or pedestrians.

There are three broad categories of AEB systems: low speed AEB, high speed AEB and AEB for vulnerable users which is designed specifically for cyclists and pedestrians. The assessment was focused on low speed AEB as this option has been included in the standard package by some manufacturers. But the benefits of high speed AEB and AEB for vulnerable users are discussed to assist the consideration of further investigation.

Side protection standards for light vehicles

Side protection standards are designed to reduce the number and severity of injuries from the intrusion of objects from the side such as narrow objects that can puncture the head, thorax, or abdomen such as poles and posts.

Side curtain airbags for light vehicles

Side curtain airbags are designed to deploy to reduce the risk and severity of injuries to the head and body because of a side impact collision. Airbags are also designed to reduce the harm caused by objects intruding into the vehicle when a vehicle leaves the road. There is an overlap between the injuries targeted by airbags and side protection standards. In addition to side protection, some systems include airbags on the ceiling in case of roll over. This variation targets the reduction of back and head injuries.

Underrun protection for heavy vehicles

Underrun protection is intended to address the height mismatch between heavy vehicles and other types of vehicles that use the road. The mismatch is associated with injuries from heavy vehicles overrunning other vehicles.

Underrun protection prevents these situations and it can also act as an early trigger for safety systems in other vehicles such as air bags, prior to an underrun incident. Underrun protection also reduces the severity of crashes by absorbing some of the vehicle energy.

3. Vehicle fleet trends

Our assessment of the options used a variety of vehicle statistics. In this section of the report we summarise the background statistics that informed our view of the likelihood of the options' technologies entering the vehicle fleet.

The size of the vehicle fleet

Estimating the potential cost of each option if it became mandatory requires an understanding of the number of vehicles affected. The table below shows the numbers of vehicles by vehicle type from 2014 to 2016.

Table 3 Vehicles in the fleet by vehicle type

Number of vehicles

Year	Light vehicles	Heavy vehicles	Motorcycles
2014	3,358,484	160,944	151,536
2015	3,485,053	167,312	157,666
2016	3,631,190	174,409	164,141
2014-2016 average	3,491,576	167,555	157,781

Source: NZIER based on Annual Vehicle Fleet Statistics 2016, (Ministry of Transport, 2017b)

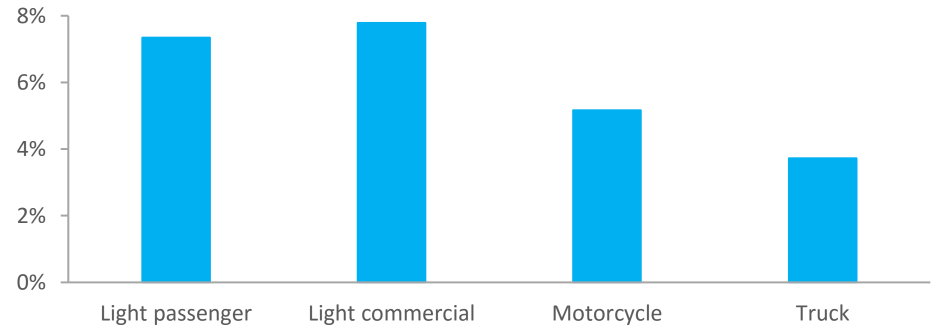
Uptake in the vehicle fleet

The uptake rate depends on scrappage and the average age of vehicles entering the fleet. The percentage of vehicles that leave the fleet, by vehicle type, is shown in Figure 1.

We used this data to inform our thinking on how quickly new technologies would enter the vehicle fleet and how long the safety benefits would endure, if the option was applied.

Figure 1 Proportion of vehicles leaving the vehicle fleet

Annual average over 5 years



Source: NZIER based on Annual Vehicle Fleet Statistics 2016, (Ministry of Transport, 2017b)

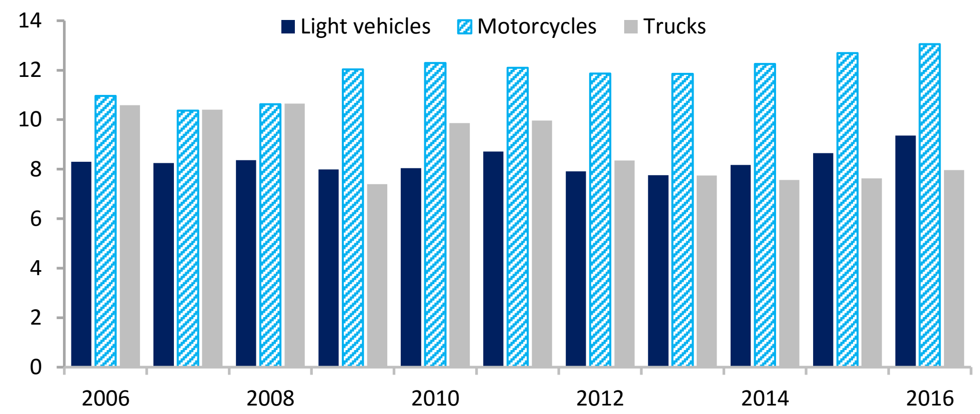
Figure 2 shows the average age of used light vehicles (passenger and commercial light vehicles combined), motorcycles and trucks when they entered the vehicle fleet.

In 2016, the average age of used light passenger vehicles was 10 years and the average age for light commercial vehicles was 9 years. The average age for motorcycles was 13 years and for trucks it was 8 years.

This indicates that standards adopted in origin markets will take 8 to 9 years to enter the fleet through used trucks and light vehicles. It will be longer for motorcycles.

Figure 2 Average age of used vehicles entering the fleet

Average age in years



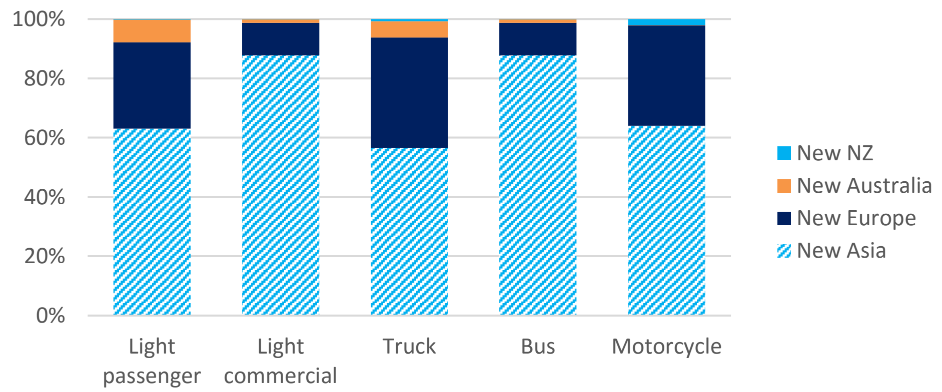
Source: NZIER based on Annual Vehicle Fleet Statistics 2016, (Ministry of Transport, 2017b)

The vehicle fleet in New Zealand is imported. Changes in vehicle technologies due to global market competition and regulation in other regions and countries affect the technologies that are present in imported vehicles.

Asia is the most common origin for new vehicles entering the vehicle fleet (see Figure 3). Asia was the origin of 73% of the new vehicles imported from 2014 to 2016. For example, vehicle options in Japan are important lead indicators for the likelihood of the options becoming available in New Zealand.

Figure 3 New imports by vehicle type and origin

Percentage of new imports 2014-2016



Source: NZIER based on Annual Vehicle Fleet Statistics 2016, (Ministry of Transport, 2017b)

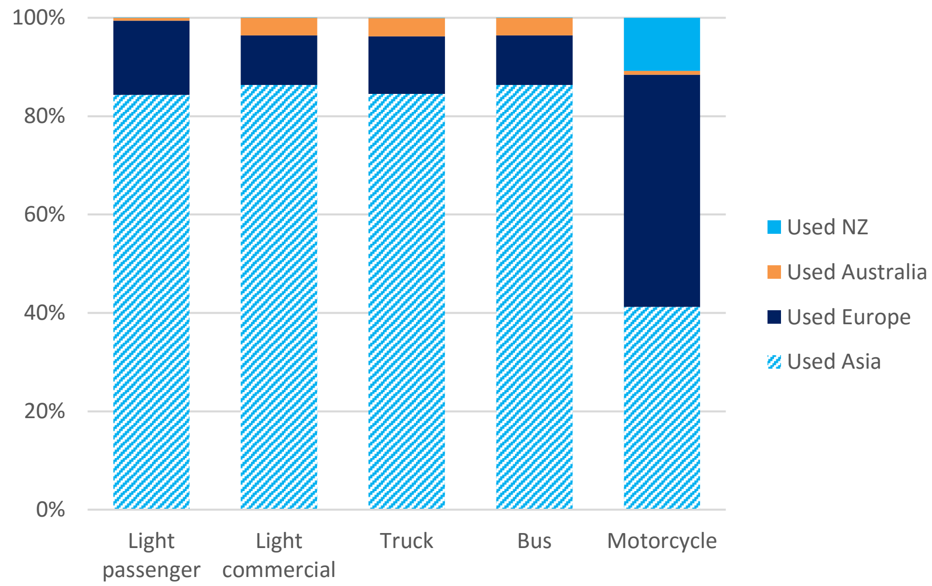
The role of Asia as a key source market for used imports entering New Zealand's vehicle fleet is more significant than for new vehicles.

Asia was the origin of 85% of the used light and heavy vehicles imported from 2014 to 2016. Some of these used vehicles would have been originally imported into Asia from Europe, so not all the used imports from Asia are from Asian vehicle manufacturers.

The pattern is different for used motorcycles. While 41% of used motorcycles came from Asia, 47% of used motorcycles came from Europe.[1] The EU tends to be an early adopter of mandatory vehicle standards, based on the literature reviewed for this project.

Figure 4 Used imports by vehicle type and origin

Percentage of used imports 2014-2016



Source: NZIER based on Annual Vehicle Fleet Statistics 2016, (Ministry of Transport, 2017b)

[1] The Europe figure for imported used motorcycles also includes imported used motorcycles from the United States.

4. ESC for heavy vehicles

ESC is designed to prevent loss-of-control crashes. It works by the vehicle detecting a loss of control or traction on any wheel and applying braking or power automatically to maintain the vehicle's stability and direction of travel. In the case of heavy vehicles, ESC reduces the risk of roll-over and jack-knife incidents (Woodrooffe et al., 2009).

There were 367 loss-of-control crashes involving trucks from 2014 to 2016. The estimated social cost of these crashes was $207 million.[2]

Table 4 Crashes involving heavy vehicles

2014-2016

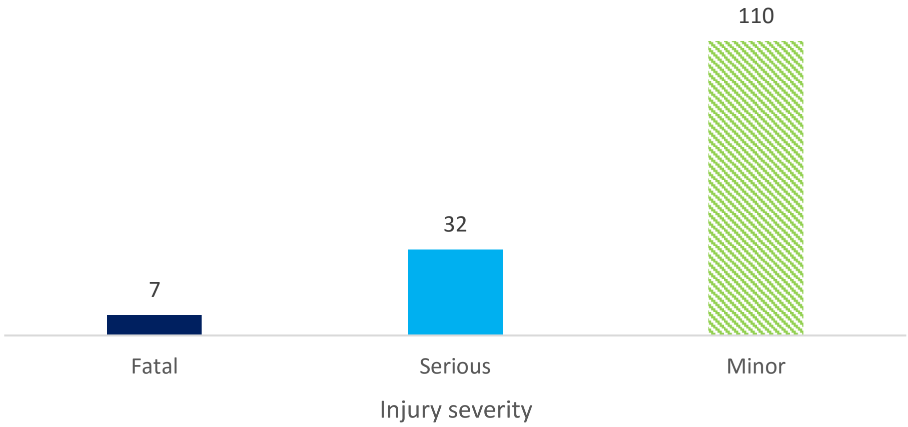
Injury severity	Fatal	Serious	Minor
Crashes	21	88	267
Injuries	23	98	337

Source: Ministry of Transport

Wang (2011) found that the effectiveness of ESC for trucks can decrease the number of loss of control and roll-over crashes by between 29% to 36%. Figure 5 shows a 32.5%[3] decrease in the number of injuries.

Figure 5 Potential decrease in heavy vehicle injuries from ESC

2014-2016, loss-of-control crashes



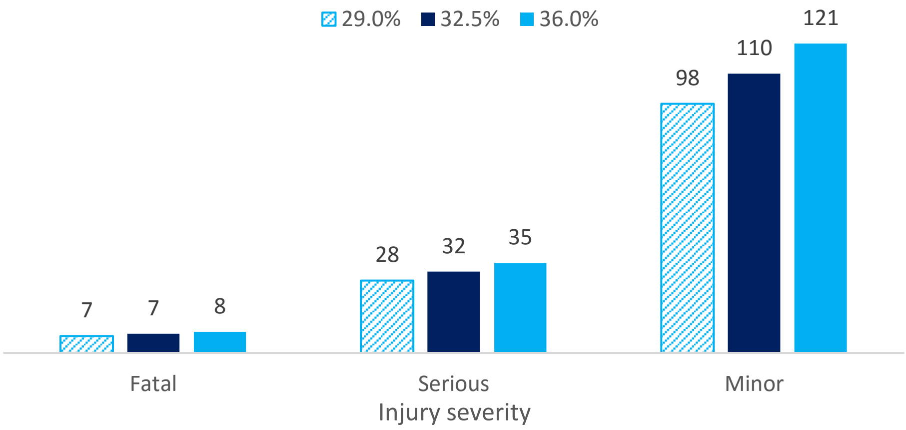
Source: NZIER based on data from the Ministry of Transport

Figure 6 below shows the sensitivity of the potential injury reduction when the upper and lower bounds from Wang (2011) are applied. The three columns represent a range of injury reduction effectiveness of 29.0%, 32.5% and 36.0%.

2 In June 2016 prices.

3 The midpoint in the range of potential benefits.

Figure 6 Potential injury reduction with the use of ESC



Source: NZIER

Other studies have found that there are safety benefits from ESC in heavy vehicles from other crashes besides loss-of-control incidents. For example, Woodrooffe et al. (2011) found that ESC for heavy vehicles reduced fatalities in crashes overall by 13% and non-fatal injuries by 6.5%. The estimated potential for overall injury reduction is shown in Table 5.

Table 5 Reduction in injuries based on Woodrooffe et al. (2011)

2014 to 2016

Injury severity	Reduction
Fatal	24
Serious	33
Minor	121

Source: NZIER based of Ministry of Transport statistics

The extent of fitment in the existing vehicle fleet in New Zealand is not known (Safer Journeys, 2017). The option is offered by several European manufacturers and has been available for several years. In 2016, 12% of used and 37% of new trucks were imported from Europe.

We assumed the fitment rate was around 30%, which is in line with the fitment rate for ABS in heavy vehicles. The cost option of ESC for new vehicles varies from $2,000 to $3,000[4] and $5,000 to $10,000[5] if it is to be retrofitted.

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4 Based on: Pearson, B., & Gardner, B. Benefits of Heavy Vehicle Stability Safety Technologies. Pearsons Transport Resource Centre Pty Ltd, Report to Queensland Department of Transport and Main Roads, Project RSSM, 07-11, adjusted exchange rates.

5 https://www.transport.govt.nz/assets/Uploads/Our-Work/Documents/Vehicle-Technologies-and-Standards-inventory-2016.pdf

Modelling approach

The assessment of the benefits and costs is based on some assumptions which we describe below:

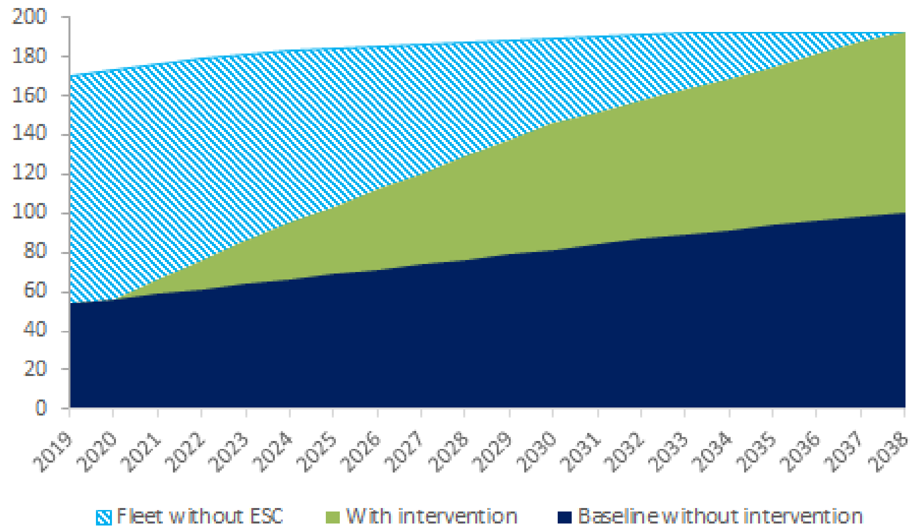
- The fitment rate in the existing fleet was assumed to be 30%.
- The ESC fitment rate increases over time in the baseline without intervention due to the number of trucks being imported from Europe.

Two scenarios were modelled. In the first scenario, all new and used trucks entering the fleet are required to have factory fitted ESC from 2021 onwards and there was no requirement to make changes to trucks already in the fleet. The second scenario required existing vehicles and vehicles entering the fleet to have ESC.

The impact of the first scenario is shown below.

Figure 7 Trucks entering are required to have factory fitted ESC

Thousands of heavy vehicles



Source: NZIER

The results for the first ESC scenario indicate that mandating ESC in trucks has the potential to generate benefits that exceed the costs, but this result does not hold when the cost of factory fitting of ESC heads up past $2,600.

More data on existing fitment rates and costs would be useful for informing decision-making.

Table 6 Trucks entering are required to have factory fitted ESC

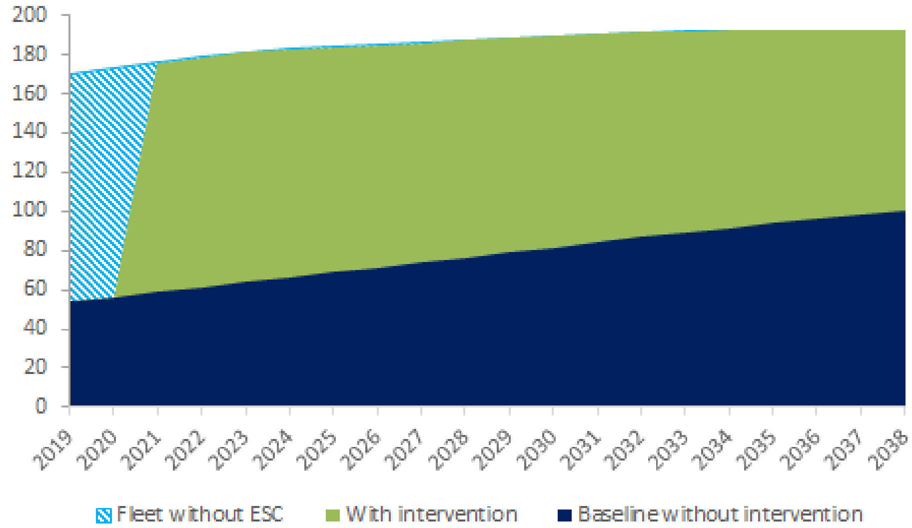
Scenario	Cost per vehicle in incoming vehicles	NPV $millions	BCR
Low	$2,000	$36.63	1.30
Medium	$2,500	$6.47	1.04
High	$3,000	-$23.69	0.87
Break-even	$2,607	$0.00	1.0

Source: NZIER

The second scenario was based on a requirement to retrofit ESC by 2021 for the existing fleet and mandatory factory fitted ESC for trucks entering the fleet. Figure 8 shows the significant change in fitment rates from 2021 onwards.

Figure 8 All trucks are required to have ESC

Thousands of vehicles



Source: NZIER

The results (Table 7) show that the costs of mandating ESC for existing and incoming heavy vehicles will exceed the benefits, unless the cost of retrofitting ESC decreases significantly.

Table 7 Initial assessment results for the ESC

Scenario	Cost per vehicle; existing vehicles	Cost per vehicle; incoming vehicles	NPV $millions	BCR
Low	$5,000	$2,000	-$231.94	0.61
Medium	$7,500	$2,500	-$499.63	0.42
High	$10,000	$3,000	-$767.32	0.32
Break-even	$2,171	$2,607	$0.3	1.0

Source: NZIER

5. ABS for motorcycles and heavy vehicles

ABS is designed to avoid a loss of traction which can result in crashes and injuries. One benefit of ABS is that it gives drivers confidence to fully apply the brakes, when they otherwise might be tentative due to the risk of lock-up. This can shorten stopping distances.

ABS also allows drivers to steer the vehicle under heavy braking, which can help them avoid objects and/or reduce the severity of a collision. It can contribute to reducing the incidence or severity of all types of crashes, but it is particularly effective in head-on and nose-to-tail crashes.

Improvements in braking and braking distances are known to contribute to a general reduction in all types of crashes for motorcycles (Green, 2006) and heavy vehicles.

ABS for motorcycles

There were 3,033 crashes involving motorcycles from 2014 to 2016. They resulted in 116 deaths, 1,115 serious injuries and 2,069 minor injuries. We estimated the social cost of the crashes and injuries was $1.69 billion for the three-year period.

ABS for motorcycles reduces the number and severity of injuries (Rizzi, Kullgren, & Tingvall, 2016). The impact of ABS for motorcycles has been analysed in several countries in a small number of published research papers. A summary of the research is shown in Table 8.

Table 8 Injury reduction from ABS in motorcycles

Source	Country	Crashes (all injuries)	Severe injury crashes
Fildes, Newstead, Rizzi, Budd, & Fitzharris (2015)	Australia	33%	39%
Rizzi, Strandroth, Kullgren, Tingvall, & Fildes (2013)	Sweden	34%	42%
	Spain	29%	34%
	Italy	24%	N/A
Rizzi, Strandroth, & Tingvall (2009)	Sweden	39%	48%

Source: NZIER literature review

The estimates of the injury reduction by Fildes et al. (2015) fall in the middle of the range of studies reviewed. Applying these results suggests that ABS in motorcycles could potentially reduce the number of deaths by 45, serious injuries by 435 and minor injuries by 683 over three years.[6]

[6] Based on injuries from 2014 to 2016.

The fitment rate for ABS on motorcycles is not known. ABS is becoming common in new motorcycles imported into New Zealand, due to regulation overseas. ABS has been mandatory for new motorcycles in the EU since 2016.

Europe is the origin of 34% of new motorcycles and 47%[7] of used motorcycles that are imported into New Zealand. It is likely that ABS will become more common in the vehicle fleet over the medium term. The effect of regulation would be to effectively standardise ABS in new motorcycles and accelerate uptake.

Off-road motorcycles are exempt in the EU (Department of Infrastructure, Transport, Regional Development and Local Government, 2015a). Whether such an exemption is warranted in New Zealand should be included in any further consideration.

Modelling approach

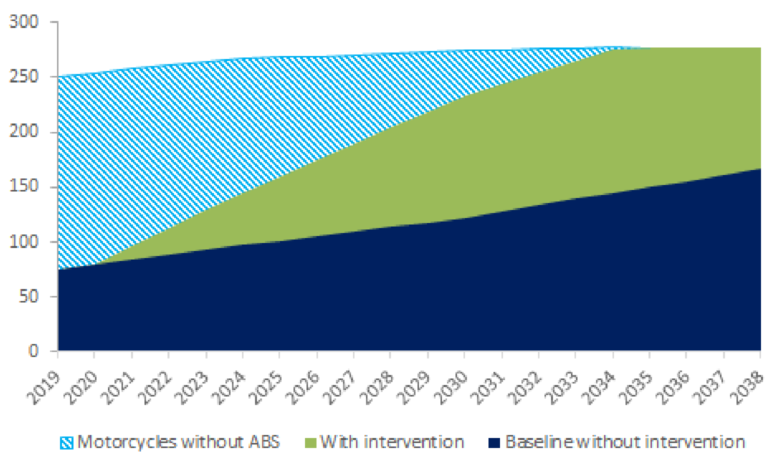
The estimation of benefits and costs of introducing the requirement of ABS for motorcycles is based on:

- The scenario was for factory fitted options only.
- The existing level of fitment was assumed to be 30%.
- ABS becomes mandatory from 2021.
- The cost is applied to vehicles entering the fleet.
- In the baseline, all new motorcycles from Europe are assumed to be equipped with ABS on arrival in to New Zealand. Motorcycles from other countries are assumed *not* be fitted with ABS.
- ABS will be common in used imports from Europe by 2031 based on the current average age of used motorcycles entering the fleet.

Figure 9 shows the level of ABS in the vehicle fleet with and without the modelled intervention.

Figure 9 ABS required on entering the fleet

Thousands of motorcycles



Source: NZIER

[7] The data used did not separately identify the proportion of used motorcycles that are from the United States.

The cost of factory fitted ABS on motorcycles is around $1,000 per vehicle. Models being sold with ABS included are currently being retailed as low as $6,000 excluding on-road costs. Retrofitting ABS is not a practical option (Safer Journeys, 2017).

The results of the modelling are shown below. The results show, based on the available information, that the benefits are likely to exceed the costs.

Further investigation is warranted. More information on the proportion of new motorcycles being sold with ABS would improve the evidence base for any future consideration.

Table 9 Results for ABS for motorcycles

Scenario	Cost per vehicle	NPV $million	BCR
Low	$500	$695.20	12.2
Medium	$1,000	$632.89	6.1
High	$2,000	$508.27	3.0

Source: NZIER

ABS for heavy vehicles

ABS for heavy vehicles has been a regulated requirement in Australia since 2013. (Department of Infrastructure, Transport, Regional Development and Local Government, 2013). The regulation makes ABS mandatory for all heavy vehicles.

The Australian cost-benefit analysis supporting the regulatory impact statement found a benefit-cost ratio of 1.5. ABS in heavy vehicles substantially improves braking performance. The effectiveness of ABS for heavy vehicles in reducing death and injuries, ranges from 3% to 8% in heavy vehicle crashes (Department of Infrastructure, Transport, Regional Development and Local Government, 2013).

The fitment rate was assumed to be 36%, which is based on the central estimates of the fitment rate for ABS in heavy vehicles in Australia.

Table 10 Potential reduction in injuries involving a heavy vehicle

2014 to 2016

Injury severity	3%	8%
Fatal	5	15
Serious	15	40
Minor	56	149

Source: NZIER based of Ministry of Transport statistics

ABS can be retrofitted. The cost of retrofitting ABS in heavy vehicles varies between $1,000 and $5,000 depending on the vehicle type. The cost for retrofitting ABS on a heavy vehicle trailer is between $1,000 and $2,000. (Department of Infrastructure, Transport, Regional Development and Local Government, 2013)

Depending on the vehicle type and whether heavy trailers are used, the cost of ABS retrofitting could range from $1,000 to $9,000 (Department of Infrastructure, Transport, Regional Development and Local Government, 2013).

Any further research would need to model a wide range of vehicle options due to the different configurations of heavy vehicles.

Modelling approach

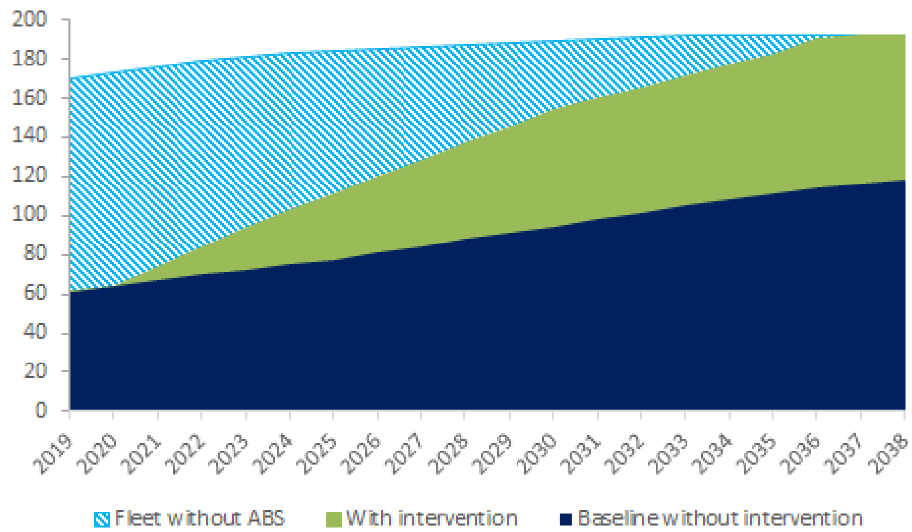
The following assumptions were applied in the baseline:

- The time horizon for the analysis was 2019-2038 (20 years), including a two-year lag for developing and implementing regulations.
- The fitment rate in the existing fleet was assumed to be 36%.
- A compliance rate of 100%.
- The results are reported in 2017 prices.
- The ABS fitment rate increases over time in the baseline without intervention due to the number of trucks being imported.
- The fitment rate in vehicles entering the fleet was assumed to be 40%.

In the modelling scenario all new and used trucks are required to have factory fitted ABS from 2021 onwards and there was no requirement to make changes to trucks already in the fleet.

Figure 10 All trucks entering the fleet are required to have factory fitted ABS from 2021

Thousands of trucks



Source: NZIER

Our initial assessment (Table 11) suggests the costs per vehicle would need to be at the lower end of the range in order for the benefits to be greater than the costs.

Overall the results are mixed. The next step should be to gather information to fill the data gaps. Further analysis should use a more detailed breakdown of the heavy vehicle fleet due to the variation in costs by truck type.

Table 11 Results for requiring trucks entering the fleet to have ABS

Scenario	Cost per vehicle	NPV $million	BCR
Low	$1,000	$22.74	1.37
Medium	$3,000	-$98.68	0.46
High	$5,000	-$220.10	0.27
Breakeven	$1,376	$0.0	1.0

Source: NZIER

6. AEB for all vehicles except motorcycles

AEB is designed to reduce the severity of frontal impact by detecting an imminent collision and acting to autonomously stop the vehicle.

There are three broad categories of AEB technologies: low speed, high speed and vulnerable user AEB, which is designed for pedestrian and cycle safety. The categories differ in terms of their ability to identify hazards; scanning range; scanning angle; computation time; and response time.

Our quantitative analysis looks only at low speed AEB technologies, as this is beginning to be offered as part of the standard package by some vehicle manufacturers.

We discuss qualitatively the potential costs and benefits of the less-common high speed AEB and AEB for pedestrian and cycle safety.

AEB is rapidly becoming part of the standard vehicle package

AEB was once seen as an optional extra, but it is rapidly becoming part of the standard package globally. The driving force behind this shift is a combination of regulatory changes and competition:

- In Europe, AEB is already mandatory for heavy vehicles. Mandatory AEB for light vehicles is being investigated.
- In the US market, the 20 top manufacturers have committed to making AEB a standard feature for cars by 2022 and heavy vehicles by 2025 (Engadget, n.d.).
- Several Japanese manufacturers, including Nissan and Toyota, have announced that they will offer low speed AEB as a standard feature in 2017 (Automotive News, 2015).
- Competition is behind the shift to include AEB as a standard feature and is linked to the emerging autonomous vehicles market. AEB is a fundamental component of this market.[8]

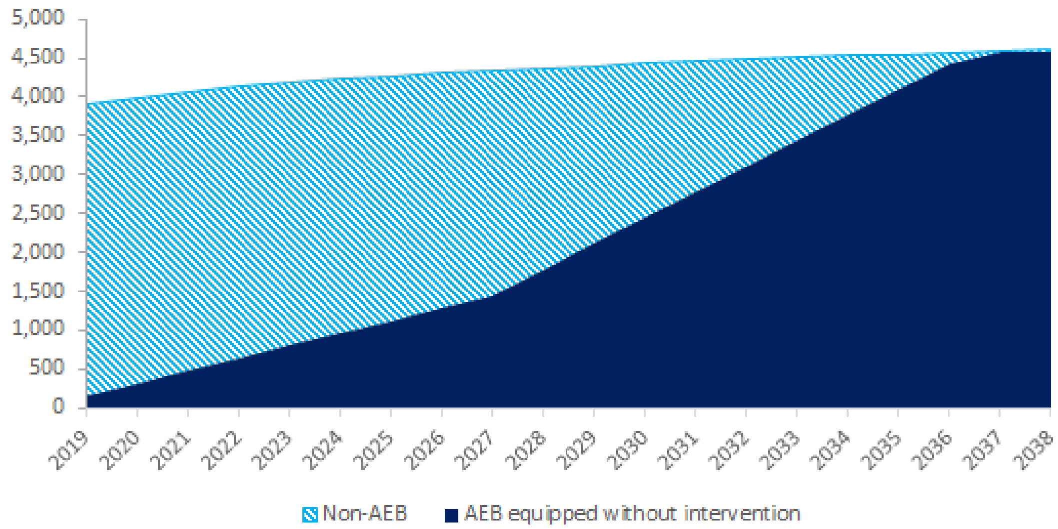
For New Zealand, this means that low speed AEB is likely to become an increasingly common feature in new imported vehicles in the next few years; and in used vehicles over the next 7 to 10 years.

By 2027, low speed AEB will enter the used vehicle fleet without additional regulatory intervention. Figure 11 shows the outlook for low speed AEB in New Zealand on the basis that it is in all new vehicles in 2018 and in used imports in the next 7 to 10 years.

8 https://www.ft.com/content/14d80bec-a297-11e4-9630-00144feab7de

Figure 11 Low speed AEB will enter the fleet without intervention

Thousands of vehicles



Source: NZIER

What are the potential safety benefits?

Frontal impact damage is quite common in crash reports. Data supplied by the Ministry showed that frontal damage was present in 11,043 crashes involving a light vehicle, and 254 crashes involving a heavy vehicle, from 2014 to 2016.

However, to be conservative we have only investigated the potential safety effects for crashes where the technology would clearly have been deployed:

- Head-on crashes
- Collision with an obstruction
- Rear-ending.

Table 12 shows the number of injuries by injury severity for light vehicles and trucks from 2014 to 2016.

Table 12 Injuries from selected frontal impact crashes types

2014-2016

Injury severity	Fatal	Serious	Minor	All
Light vehicles				
Head-on	56	252	624	932
Collision with an obstruction	1	68	512	581
Rear-ending	2	87	1,661	1,750
Total	59	407	2,797	3,263
Heavy vehicles (trucks)				
Head-on	0	3	28	31
Collision with an obstruction	1	2	14	17
Rear-ending	0	1	39	40
Total	1	6	81	88

Source: Ministry of Transport

International research shows that low speed AEB systems can reduce injuries by 38% for low speed[9] rear-end crashes, compared to vehicles without low speed AEB (Fildes et al., 2015).

If a similar pattern of safety effects was experienced for head-on crashes and collisions with an obstruction, in addition to rear-end crashes, low speed AEB is estimated to potentially reduce the number of deaths by 23 and serious injuries by 157, over three years.

However, due to the low speed parameters of the types of AEB considered, we would not expect a large fall in the number of vehicle occupant deaths and severe injuries. Using the statistics in the table above would overestimate the effect as they are not adjusted for the speed of the crash. It is better to consider the potential reduction in deaths and severe injuries involving cyclists and pedestrians.

Pedestrians and cyclists were not covered as thoroughly as other road users due to information gaps. We know there were 93 pedestrian fatalities and 2,529 injuries from 2014 to 2016. Over the same period, there were 21 cyclist deaths and 2,207 injuries. The majority of pedestrian (55%) and cyclist (65%) deaths occur on urban roads, where speeds are less than 70km/h (Ministry of Transport, 2017a).

[9] Low speed is operating under 30 km/h.

From 2014 to 2016, the estimated number of pedestrian and cyclist fatalities on urban roads was 63 and 15, respectively. A 38% reduction in those fatalities would be a reduction of 26 fatalities over three years or 8 to 9 lives saved per year.

AEB cannot be retrofitted (www.howsafeisyourcar.com.au, n.d.). The cost of low speed AEB as an option ranges from $400 to $2,500 depending on the specifications sought (Thatcham Research, n.d.). However, the cost is likely to fall as AEB becomes more common.

We assumed the cost of a low speed AEB to be $500, which was higher than the cheapest option but at the lower end of the range (Healey, 2016). The AEB fitment rate is less than 1% among new imports in New Zealand (Safer Journeys, 2017).

Modelling approach

The benefits and costs of introducing the requirement of AEB are based on it being a requirement for all vehicles except motorcycles from 2021.

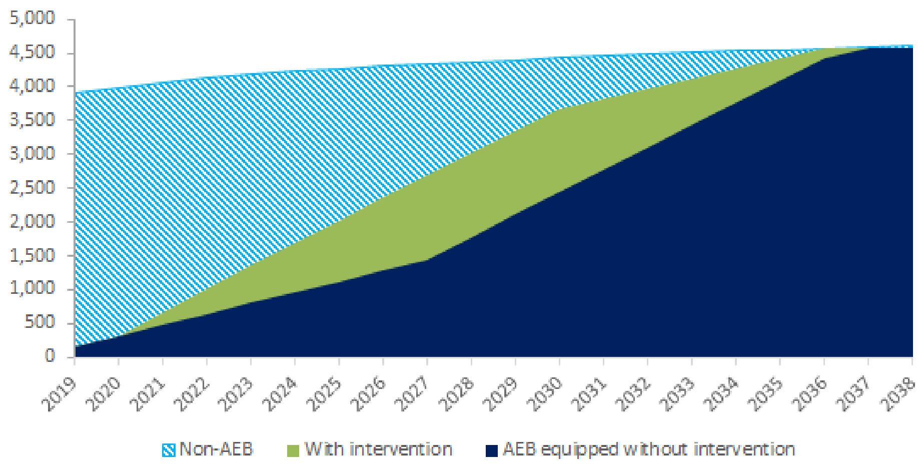
The estimate was based on:

- The scenario was for factory fitted low speed options only.
- The existing level of fitment was 1%.
- The cost is applied to vehicles entering the fleet that wouldn't be fitted with low speed AEB without intervention.

Figure 12 shows the level of low speed AEB in the vehicle fleet with and without the modelled intervention.

Figure 12 AEB in the fleet with and without intervention

Thousands of vehicles



Source: NZIER

Table 13 shows the results of the modelling for low, medium and high costs, plus the breakeven cost.

Table 13 Low speed AEB modelling results

Scenario	Cost per vehicle	NPV $million	BCR
Low	$400	-$65.96	0.8
Medium	$500	-$135.82	0.6
High	$2,000	-$1,183.73	0.2
Breakeven	$306	$0.00	1.0

Source: NZIER

In this initial assessment, the costs exceeded the benefits suggesting this option would be a relatively low priority compared to the other options.

One of the reasons why this option did not come out as strongly as some of the others is because the injury intensity (the avoided fatal and serious injuries as a proportion of all avoided injuries) was relatively lower for this option.

The benefits of high speed AEB are expected to be higher because the risk of fatal and serious injuries is correlated with increased speed at the time of the crash. The costs will also be higher due to the additional level of technology involved. High speed AEB can be combined with forward collision warming systems (FCW) that scan the road up to 200m ahead of the vehicle. They can increase the time AEB has to respond to a risk of a collision. In the case of head-on high-speed risks, AEB does not always avoid a crash, but it reduces the speed of the crash and the risk of serious injury.

Vulnerable user AEB works at low speeds to detect pedestrians and cyclists moving in the path of the vehicle from the side rather than from the front. It is less common than low speed AEB. This technology option could be considered in the future.

7. Side impact technologies

Side impact technologies are principally curtain airbags that deploy to reduce the risk and severity of injuries to the head and body after a side impact collision.

Side impact airbags are also designed to reduce the harm caused by objects intruding into the vehicle when it leaves the road. There is therefore an overlap between the injuries targeted by airbags and side protection standards.

Table 14 shows the number and severity of injuries from light vehicle crashes with damage to the side of the vehicle from 2014 to 2016.

Table 14 Injuries from crashes with side impact vehicle damage

2014-2016

Injury severity	Injuries
Fatal	65
Serious	401
Minor	2,581

Source: Ministry of Transport

An Australian study found that side impact protection reduces the risk of injury or death by 41% (D'Elia, Newstead, & Scully, 2013).

When airbags are combined with side impact protection the effectiveness increases by a further 5% (Jakobsson et al., 2010). The combined effectiveness of the airbags and side impact protection was estimated to be 46%.

Table 15 Reduction in injuries from side impact technologies

2014-2016

Injury severity	Side airbags only	Side airbags and side impact protection
Fatal	27	30
Serious	164	186
Minor	1,058	1,195

Source: NZIER based on Ministry of Transport statistics

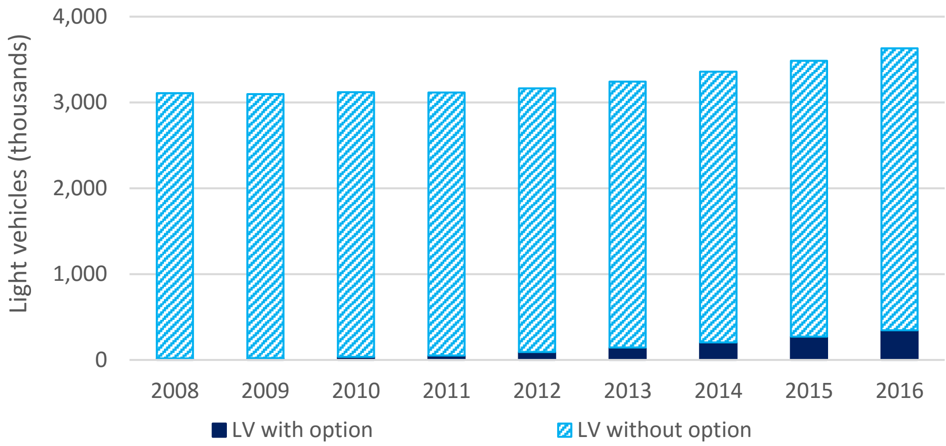
Side airbags have been mandatory in the US for all new light vehicles since 2012 (National Highway Traffic Safety Administration, 2007). The cost of side airbags is around $300 per vehicle (Department of Infrastructure, Transport, Regional Development and Local Government, 2015b). Side airbags have been a standard feature in Toyota vehicles in Japan since 2007 (Toyota Global Newsroom, 2007).

According to the Safer Journeys (2014) *Vehicle Standards Map* the fitment rate for new vehicles available in New Zealand is over 90% (95% in light passenger vehicles and 70%

to 80% of light commercial vehicles). If this has been the case since 2008, then the fitment rate in the light vehicle fleet is around 10% based on the average age of used light passenger (8 years) and light commercial (10 years) vehicles when they enter the vehicle fleet.

The graph below shows the most likely scenario of fitment in the light vehicle fleet (light passenger and light commercial vehicles combined) since 2008.

Figure 13 Fitment of side curtain airbags in light vehicles



Source: NZIER based on data from the Ministry of Transport Vehicle Fleet Statistics

Given the level of fitment on new imports and the length of time since at least one Japanese manufacturer made side airbags a standard option, it seems likely that they will become more prevalent in the vehicle fleet without intervention.

If side airbags were introduced overseas as a standard feature in light vehicles in 2007, then they will begin to enter the vehicle fleet as used imports in the next two years.

Modelling approach

The benefits and costs of introducing the requirement of side airbags in all light passenger and commercial vehicles entering the fleet were based on a range of assumptions. The assumptions for the base case and scenario are described below.

Baseline assumptions:

- The scenario was for a factory fitted option rather than retrofitted.
- The existing level of fitment was 15% in the vehicles in the fleet.
- The level of fitment in new light passenger vehicles was 95%.
- The level of fitment in new light commercial vehicles was assumed to be 75%.
- Used light passenger vehicles have the same rate of fitment as new vehicles from 2021.
- Used light commercial vehicles have the same rate of fitment as new vehicles from 2019.

Intervention scenario assumptions:

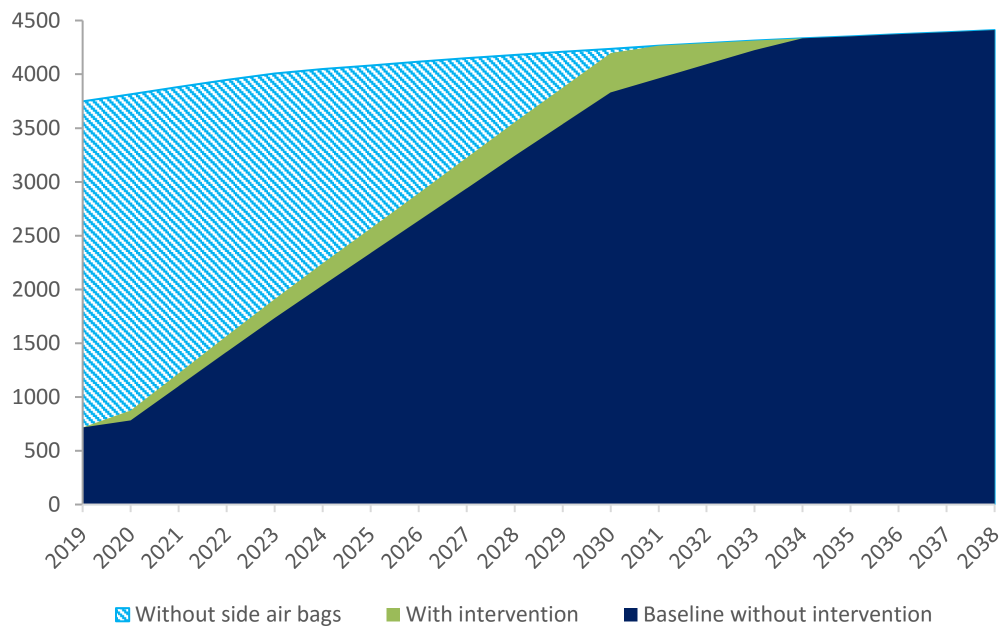
- The rate of fitment of new and used light passenger and commercial vehicles increases from the relevant baseline rates to 100% in 2021.
- An additional cost per vehicle for the low, medium, high scenarios of $100, $300, $500, respectively.

The figure below shows the fitment rate in the projection for the combined light passenger and commercial vehicle fleet under the baseline without intervention scenario and the with intervention scenario.

The with-intervention scenario makes only a small difference to the fitment rate in the fleet compared to the baseline as the rate of fitment in the baseline is expected to increase substantially once the technology becomes common in used imports.

Figure 14 Vehicles with side airbags with and without intervention

Light passenger and commercial vehicles (thousands)



Source: NZIER

Table 16 below shows the net present value and BCR for the high, medium, low and breakeven cost scenarios from intervening to increase the rate of fitment of side airbags compared to the baseline of no intervention. The results of the initial assessment show that intervening to accelerate the rate of fitment for side airbags is not likely to have benefits that exceed the costs.

The results are unsurprising given the likelihood that side airbags have been entering the vehicle fleet in new light vehicles for several years and this technology is likely to be common in used imports in the short to medium term.

Table 16 Side bags initial assessment results

Scenario	Cost per vehicle	NPV $millions	BCR
Low	$100	-$18.25	0.4
Medium	$300	-$75.18	0.1
High	$500	-$132.12	0.07
Breakeven	$36	$0.00	1.0

Source: NZIER

The next step for considering the use of side airbags is to consider monitoring the rate of fitment in used imports to establish a clear evidence base about the ongoing availability of the safety technology in the vehicle fleet over the medium term.

Side pole protection reduces the risk of injuries by an additional 5%, on top of the side airbags. It is difficult to distinguish side impact standards from side pole protection because the systems are often installed and used in combination. Better information on the rate of fitment of side pole protection is needed before this can be assessed in more detail.

8. Underrun protection

Underrun protection is designed to address the height mismatch in size between trucks and other vehicles. It can be retrofitted to the front, side and rear of heavy vehicles if enough clearance is maintained. Underrun protection devices vary in the level of energy they are designed to absorb.

The aim of underrun protection is to protect occupants of other vehicles, motorcycles and cyclists, rather than truck occupants. Front and rear underrun protection systems aim to reduce injuries and injury severity of people in motor vehicles. Side underrun protection is designed to reduce harm to those not protected by the body of a motor vehicle (i.e. cyclists and motorcyclists). Around one-third of cyclist fatalities involve a truck (Cycle Safety Panel, 2014).

Data limitations hampered our investigations of the potential safety effects of underrun protection devices in New Zealand. Current crash data does not specify when a truck crash involves underrunning, so it was not possible to get a clear picture of the extent of underrun incidents and the associated severity of injuries.

One avenue for further investigation may be the detail reported by police for individual crash reports. Such a review was not in the scope of this research.

The UK and EU have underrun protection regulations

Underrun protection has been a requirement for heavy vehicles in the UK since the 1980s, with exceptions for some circumstances (Transport for London, 2012). It was considered to be affordable (and straightforward) to retrofit in the UK, with a typical installation time of less than a day. The systems vary based on the make and model of the truck or trailer. [10]

What do we know about crashes involving trucks?

The potential benefits of underrun protection are experienced by drivers or passengers in vehicles other than trucks. There were 157 deaths from crashes involving trucks and one or more other vehicles[11] from 2014 to 2016. Table 17 below shows the crash and injury statistics for multi-vehicle crashes involving a truck.

10 fors-online.org.uk/resource.php?name=RS1_4_03_underun

11 Truck only and truck versus truck crashes were excluded.

Table 17 Multi-vehicle crashes involving a truck

2014-2016

Injury severity	Crashes	Injuries
Fatal	125	157
Serious	304	394
Minor	1,049	1,504

Source: NZIER based on data from Ministry of Transport

It is not known what proportion of these crashes involved underrunning. However, the potential for underrun incidents is high given the frequent mismatch between trucks and other vehicles. So, it was assumed that 25% of injuries involved underrunning.

Underrun protection has been estimated to reduce deaths and serious injuries by 25%-39% and 34%-50%, respectively (Department of Infrastructure, Transport, Regional Development and Local Government, 2007).

Table 18 shows the estimated potential reduction in injuries due to the use of underrun protection.

Table 18 Possible reduction in injuries due to underrun protection

2014-2016

Injury severity	Reduction rate	Injuries avoided
Fatal	29.5%	12
Serious	44.5%	44
Minor	44.5%	167

Source: NZIER based on data from Ministry of Transport

Information gaps about the rate of fitment in New Zealand

The rate of fitment in New Zealand is not known and further consultation with the road freight industry is needed to establish the extent of existing use. Our review of similar investigations in other countries found similar information gaps – New Zealand is not an outlier regarding issues understanding fitment rates.

Gathering better information about the extent of fitment in New Zealand is recommended if officials wish to pursue further consideration of introducing mandatory requirements for underrun protection.

The cost of retrofitting underrun protection

Some manufacturers in New Zealand offer underrun protection as either as an optional extra on a new vehicle or as an after sales add-on. Retrofit side underrun protection systems are available in New Zealand for $500 excluding GST and installation costs.[12]

Anecdotally, distributors in New Zealand believe the cost would fall if the demand increased due to economies of scale and improved logistics from cost efficiency. For this assessment it was assumed that the estimated cost of the combination front, rear and side underrun protection in New Zealand is around $2,000 excluding GST.

In the sensitivity analysis, lower and upper estimates of $1,000 and $3,000, respectively were applied.

Modelling approach for trucks versus other vehicles

The benefits and costs of introducing the requirement of underrun protection for trucks were based on it being mandatory for all light and heavy trucks from 2021. The estimate was based on:

- The scenario was for retrofitting rather than the factory option.
- The cost estimate includes installation costs.
- The existing level of fitment was 30% in the vehicles in the fleet and imports.
- An annual safety improvement through the avoidance of 8 deaths, 29 serious injuries and 112 minor injuries.

Table 19 shows the results of the initial assessment for underrun protection. The benefits exceed the costs in this initial assessment.

The information gaps are considerable, however, and these results are not robust enough to use as basis to proceed to a policy change.

Table 19 Underrun assessment

Scenario	Cost per vehicle	NPV (millions)	BCR
Low	$1,000	$169.13	2.0
Medium	$2,000	-$5.01	1.0
High	$3,000	-$179.14	0.7

Source: NZIER

The analysis did not include safety benefits for cyclists and pedestrians due to information gaps. As a result, the results are conservative. As discussed around one-third of cyclist crashes involve a truck.

12 Cost estimate supplied by a New Zealand based distributor.

Table 20 Cycling fatalities

Year	Fatalities	Injuries	Estimated fatalities with truck involved	Estimated injuries with truck involved
2014	10	733	3.3	244
2015	6	745	2.0	248
2016	5	729	1.7	243

Source: NZIER and Ministry of Transport Cycle Crash Facts 2017

Further research is needed to fill data gaps

There are material gaps in the evidence base needed for a detailed assessment of underrun protection:

- Understanding how many injuries are associated with underrun incidents in New Zealand.
- Cyclist and pedestrian injuries associated with underrunning and trucks in New Zealand.
- The extent of fitment in the current vehicle fleet.
- The extent of fitment in vehicles entering the fleet.

The benefits of side underrun protection are not limited to safety. Dutch and US research have shown that 'closed-in' side underrun protection can improve the aerodynamics of heavy vehicles which improves fuel efficiency, reducing fuel costs and vehicle emissions.

The estimated reduction in fuel costs ranges from 1% to 7% depending on the truck-trailer combination (Volpe, The National Transportation Systems Centre (2015) and Dutch Road Safety Research Institute (1996)).

We have not included these additional benefits in the comparison for this assessment as we wanted to maintain comparability across all the options.

It is recommended that the potential for aerodynamics benefits be explored in any further research. Understanding the extent of fitment and whether 'open' or 'closed in' side protection is fitted will be important any further assessment.

9. Conclusion

We assessed a range of vehicle safety options and considered the following questions:

- Which options are likely to have benefits that exceed the costs?
- Which options should be prioritised for further assessment?
- What is the likelihood that the options will enter the vehicle fleet without intervention?

The scope of the research was limited to a preliminary assessment of the benefits and costs. The purpose of the research was to inform decision-making about prioritising potential future research. The research was not intended to directly lead to regulation and the results should not be treated as robust enough to move directly to regulatory changes.

We identified significant information gaps while undertaking this research. Consequently, the results are uncertain in several cases, in part because the rate of fitment was not known or uncertain for many of the options.

The overall results for the options are shown in Table 21. The table shows the estimated ratio of the benefits and costs of each option. It also provides a guide to the sensitivity of those results. A BCR equal to or greater than one implies the benefits equal or exceed the costs. We recommend the green options for prioritisation. The amber options need more data on fitment or injuries. We do not recommend the red options be prioritised.

Table 21 Summary of the assessment of potential benefits and costs

Option	Low BCR	Medium BCR	High BCR
ESC[1] for heavy vehicles entering the fleet	0.9	1.0	1.3
ESC[1] for all heavy vehicles	0.3	0.4	0.6
ABS[2] for motorcycles	3.0	6.1	12.2
ABS for heavy vehicles	0.3	0.5	1.4
Low speed AEB[3] for all vehicles excluding motorcycles	0.2	0.6	0.8
Side impact (airbags) for light vehicles	0.07	0.1	0.4
Underrun protection for heavy vehicles	0.7	1.0	2.0

Notes: 1 Electronic stability control 2. Anti-lock braking systems 3. Autonomous emergency braking

Source: NZIER

ESC for heavy vehicles

The results of the assessment of ESC for heavy vehicles depend on whether the assessment includes only vehicles entering the fleet or a combination of vehicles in the fleet and those entering.

The cost of retrofitting ESC is three times higher than factory fitted ESC.

We found the benefit only exceeded the cost for factory fitted ESC on vehicles entering the fleet.

We recommend more investigation of ESC of vehicles entering the fleet with factory fitted ESC. We do not recommend further consider of retrofitting ESC to heavy vehicle already in the fleet.

ABS for motorcycles

The benefits of ASB for motorcycles are likely to exceed the costs.

ABS appears to be becoming more common in new motorcycles being offered to consumers. More precise information on the proportion of new motorcycles being sold with ABS would improve the evidence base for future analysis.

We recommend this option should be prioritised for further consideration.

ABS for heavy vehicles

The benefits of ABS for heavy vehicles were not likely to exceed the cost under the medium scenario. The fitment rate and costs of installation were uncertain for this option. The costs vary significantly depending on the vehicle configuration.

We do not recommend that this option be prioritised for further assessment, relative to others explored in this report.

The next step for this option would be to fill the information gaps before undertaking any further assessment.

Low speed AEB for all vehicles except motorcycles

AEB is a technological requirement for autonomous vehicles and is likely to become more common as manufacturers compete for this emerging market. AEB includes three broad categories including low speed, high speed and AEB specifically designed for cycle and pedestrian safety.

Japanese vehicle manufacturers have recently announced that they will include low speed AEB as standard in light vehicles. The assessment focused on low speed AEB rather than the other two categories of AEB.

The benefits of low speed AEB did not exceed the costs because the impact of the technology was associated with a lower injury intensity profile due to lower speeds. High speed AEB could deliver larger injury benefits because it has been shown to reduce the risk of severe and fatal injuries more than low speed AEB.

We recommend that a monitoring programme is developed for AEB technologies to gather information on the fitment rate among vehicles entering the fleet. This should distinguish between the three broad categories of AEB.

Side impact technologies

Side airbags have been entering the vehicle fleet in new light vehicles for several years and we have reached a point in time where it is likely to be common in used imports in the short to medium term.

We do not recommend this option is prioritised for further assessment. The benefits are not likely to be greater than the costs.

Underrun protection for heavy vehicles

There are significant information gaps in the assessment of this technology. For example, there are no official statistics on the number and severity of underrun crashes or the fitment rate of underrun protection in the existing fleet. The assessment required several assumptions to assess the potential benefits and costs.

The results of the assessment indicate that the benefits could potentially exceed the costs.

However, we recommend that before a more robust assessment can take place the Ministry needs to develop some official statistics about underrun crashes. This should include statistics for side underrun crash injuries for motorcyclists, cyclist and pedestrians.

Developing these statistics should be a priority as the benefits from the statistics would also benefit other future investigations.

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Appendix A Crash types

Table 22 Movement classifications for crashes

	TYPE	A	B	C	D	E	F	G	O
A	OVERTAKING AND LANE CHANGE	PULLING OUT OR CHANGING LANE TO RIGHT	HEAD ON	CUTTING IN OR CHANGING LANE TO LEFT	LOST CONTROL (OVERTAKING VEHICLE)	SIDE ROAD	LOST CONTROL (OVERTAKEN VEHICLE)	WEAVING IN HEAVY TRAFFIC	OTHER
B	HEAD ON	ON STRAIGHT	CUTTING CORNER	SWINGING WIDE	BOTH OR UNKNOWN	LOST CONTROL ON STRAIGHT	LOST CONTROL ON CURVE		OTHER
C	LOST CONTROL OR OFF ROAD (STRAIGHT ROADS)	OUT OF CONTROL ON ROADWAY	OFF ROADWAY TO LEFT	OFF ROADWAY TO RIGHT					OTHER
D	CORNERING	LOST CONTROL TURNING RIGHT	LOST CONTROL TURNING LEFT	MISSED INTERSECTION OR END OF ROAD					OTHER
E	COLLISION WITH OBSTRUCTION	PARKED VEHICLE	ACCIDENT OR BROKEN DOWN	NON VEHICULAR OBSTRUCTIONS (INCLUDING ANIMALS)	WORKMANS VEHICLE	OPENING DOOR			OTHER
F	REAR END	SLOW VEHICLE	CROSS TRAFFIC	PEDESTRIAN	QUEUE	SIGNALS	OTHER		OTHER
G	TURNING VERSUS SAME DIRECTION	REAR OF LEFT TURNING VEHICLE	LEFT SIDE SIDE SWIPE	STOPPED OR TURNING FROM LEFT SIDE	NEAR CENTRE LINE	OVERTAKING VEHICLE	TWO TURNING		OTHER
H	CROSSING (NO TURNS)	RIGHT ANGLE (70° TO 110°)							OTHER
J	CROSSING (VEHICLE TURNING)	RIGHT TURN RIGHT SIDE		TWO TURNING					OTHER
K	MERGING	LEFT TURN IN	RIGHT TURN IN	TWO TURNING					OTHER
L	RIGHT TURN AGAINST	STOPPED WAITING TO TURN	MAKING TURN						OTHER
M	MANOEUVRING	PARKING OR LEAVING	'U' TURN	'U' TURN	DRIVEWAY MANOEUVRE	PARKING OPPOSITE	ANGLE PARKING	REVERSING ALONG ROAD	OTHER
N	PEDESTRIANS CROSSING ROAD	LEFT SIDE	RIGHT SIDE	LEFT TURN LEFT SIDE	RIGHT TURN RIGHT SIDE	LEFT TURN RIGHT SIDE	RIGHT TURN LEFT SIDE	MANOEUVRING VEHICLE	OTHER
P	PEDESTRIANS OTHER	WALKING WITH TRAFFIC	WALKING FACING TRAFFIC	WALKING ON FOOTPATH	CHILD PLAYING (TRICYCLE)	ATTENDING TO VEHICLE	ENTERING OR LEAVING VEHICLE		OTHER
Q	MISCELLANEOUS	FELL WHILE BOARDING OR ALIGHTING	FELL FROM MOVING VEHICLE	TRAIN	PARKED VEHICLE RAN AWAY	EQUESTRIAN	FELL INSIDE VEHICLE	TRAILER OR LOAD	OTHER

Source: Ministry of Transport, Motor Vehicle Crashes in New Zealand 2016[13]

13 http://www.transport.govt.nz/research/roadcrashstatistics/motorvehiclecrashesinnewzealand/motor-vehicle-crashes-in-new-zealand-2016/

Appendix B Social costs

The Ministry estimates the social costs of crashes and injury annually. The most recent estimates for the social costs of fatal, serious and minor injuries are shown in the Table 23.

Table 23 Social costs of injuries

In June 2016 prices

Injury severity	Social cost
Fatal	$4,179,700
Serious	$776,000
Minor	$77,000

Source: Ministry of Transport

The social costs of injuries include the following components:

- Loss of life and life quality
- Loss of output due to temporary incapacitation
- Medical costs
- Emergency services and judicial system legal costs
- Vehicle damage costs.[14]

[14] http://www.transport.govt.nz/assets/Uploads/Research/Documents/Social-cost-of-road-crashes-and-injuries-2016-update-final.pdf