Bus Fire Safety Report

Bus Fire and Thermal Incidents in NSW from 2013-2022

otsi.nsw.gov.au

Office of Transport
Safety Investigations

Bus Fire Safety Report

Bus Fire and Thermal Incidents in NSW from 2013-2022

Released under the provisions of
Section 45C (2) of the *Transport Administration Act 1988* and
Section 46BBA (1) of the *Passenger Transport Act 1990*

Investigation Reference I02032

Published by: Office of Transport Safety Investigations
Postal address: PO Box A2616, Sydney South NSW 1235
Office location: Level 17, 201 Elizabeth Street, Sydney NSW 2000
Telephone: 1800 180 528
Accident and incident notification: 1800 677 766
Email: engagement@otsi.nsw.gov.au
Website: www.otsi.nsw.gov.au

About the Office of Transport Safety Investigations (OTSI)

OTSI is an independent NSW authority which contributes to the safe operation of bus, ferry and rail passenger and rail freight services in NSW by investigating safety incidents and accidents and transport safety risks, identifying system-wide safety issues, and sharing lessons with transport operators, regulators, and other stakeholders.

OTSI is empowered under the *Transport Administration Act 1988* to independently investigate rail, bus, and ferry accidents and incidents in accordance with the provisions of the *Passenger Transport Act 1990* and *Marine Safety Act 1998.* It also conducts rail investigations on behalf of the Australian Transport Safety Bureau under the *Transport Safety Investigation Act 2003 (Cth)*.

OTSI investigations are independent of regulatory, operator or other external entities. OTSI investigates using a 'no-blame' approach to understand why an occurrence took place and to identify safety factors that are associated with an accident and incident. It makes recommendations or highlights actions that transport operators, regulators and government can take to prevent recurrence and improve safety.

Evidence obtained through an OTSI investigation cannot be used in any criminal or civil proceedings. While information gathered by OTSI in the conduct of its work is protected, the Chief Investigator, under the *Transport Administration Act 1988*, may disclose information if they think it is necessary for the safe operation of a transport service.

OTSI does not investigate all transport safety incidents and accidents but focuses its resources on those investigations considered most likely to enhance bus, ferry, or rail safety.

Many accidents result from individual human or technical errors which do not involve safety systems so investigating these in detail may not be justified. In such cases, OTSI will not generally attend the scene, conduct an in-depth investigation, or produce an extensive report.

OTSI may request additional information from operators or review their investigation reports which may lead to several actions, such as the release of a Safety Advisory or Alert to raise industry awareness of safety issues and action.

OTSI investigators normally seek to obtain information cooperatively when conducting an investigation. However, where it is necessary to do so, OTSI investigators may exercise statutory powers to conduct interviews, enter premises and examine and retain physical and documentary evidence.

Acknowledgements

In the preparation of this report, OTSI consulted with, referred to, or obtained data from several key industry partners and national and international government agencies, as detailed below. Their support and cooperation are acknowledged and greatly appreciated.

- Australian Bureau of Statistics
- Australasian Bus and Coach
- Bureau of Infrastructure and Transport Research Economics
- Bureau of Meteorology
- Bus Industry Confederation
- Bus Safety, Safe Transport Victoria
- BusNSW
- Department of Fire and Emergency Services, Government of Western Australia
- Home Office, United Kingdom
- HoustonKemp, Economists
- Passenger Transport, Department of State Growth, Tasmania
- Transperth, Regional and School Bus Services, Public Transport of Western Australia
- Transport for NSW

Executive summary

From 2013 to 2022, the Office of Transport Safety Investigations (OTSI) recorded 816 notifications of bus fire and thermal incidents in NSW. The frequency of these incidents has significantly increased in recent years, with 2022 registering the highest number of incidents on record. This report aims to 1) highlight the health, social and economic impacts of bus fire and thermal incidents in NSW, 2) investigate the causes and potential contributing factors to these incidents, 3) review the effectiveness of existing fire safety interventions, and 4) make evidence-based recommendations for bus fire safety improvement. Additionally, the report benchmarks NSW incidence rates against national and international evidence and highlights the need for improvement in bus fire safety by projecting incidence rates and their associated costs over the next decade.

This executive summary provides an overview of the key findings of this report along with OTSI's recommendations and areas for further investigation. All economic estimates are given in present value terms and are expressed in 2022 Australian dollars.

Key findings

Impact

Bus fire and thermal incidents from 2013 to 2022 are estimated to have cost NSW $203 million. This includes destruction or significant damage of 52 buses and an average of 30 minutes lost by every onboard bus passenger due to travel delays arising from these incidents. Without further improvement in bus fire safety, it is projected that these incidents will continue to rise, costing NSW a further $265 million over the next decade (i.e. 2023-2032).

There were zero reported fatalities and only four minor injuries in the last decade. However, many drivers reported feeling anxious and had trouble sleeping after the incident. Some even left the profession. There is currently no formal mechanism to capture the psychological impact of bus fire and thermal incidents on the people involved.

Despite the increase in bus fire and thermal incidence rates in recent years, the severity of damage caused to the involved bus has decreased. This suggests that the existing bus fire mitigation technologies have likely been effective at reducing the severity of the incident, and at least part of the increase in incidence rates can be attributed to increased fire safety awareness and better reporting by bus operators. It was found that even minor incidents with no damage to the involved bus could have a significant impact through disruption to passengers across the bus network and to other road users.

Origins

Most bus fires in the last 10 years originated in the engine bay of the bus. The percentage of engine bay fires, however, has slightly reduced in recent years, likely due to the installation of engine bay fire suppression systems (EBFSS) in Transport for NSW (TfNSW) contracted and some other buses.

Initial indications have suggested an increase in the percentage of bus fires originating in the body of the bus, where no automatic fire suppression systems are required as part of the Australian Design Rules (ADRs) and TfNSW bus procurement panels.

Most bus thermal incidents originated in the wheel well area. However, the relative percentage of thermal incidents originating from the engine bay, body or wheel well of the bus has remained unchanged. This suggests that previous fire safety interventions and initiatives have likely had minimal impact on their occurrence.

Causes

Electrical faults were the most common cause of bus fires in the past decade, emphasising the need for improvement in areas such as configuration management, maintenance, inspection of electrical components and electrical design.

No significant change in the percentage of bus fires caused by brakes, electrical, fluid, or mechanical problems was observed, suggesting that the current bus fire safety interventions and initiatives have likely had limited impact on the root causes of fires.

Most thermal incidents in the last 10 years were caused by brake problems. Further investigation into brake-related issues is required to develop targeted fire safety solutions.

Potential contributing factors

Bus age, weather conditions and bus year of manufacture were investigated as potential contributing factors. Bus age was found to correlate with increased incidence rates until ~14-16 years old (for fires) and ~10 years old (for thermals). After this bus age, fire incidence rate stays about the same, whereas thermal incidence rate likely decreases. Initial evidence also suggests that for buses involved in a fire, the likelihood of a bus sustaining severe damage likely increases with bus age.

Weather conditions were found to have no effect on the likelihood of a bus fire. Bus thermal incidence rate, however, was found to likely increase in colder weather conditions. Contrary to common perception, hotter weather conditions are not a contributing factor to bus fire and thermal incidents.

Buses manufactured in 2004 had the highest annual fire incidence rate, and buses manufactured in 2009-2011 had the highest thermal incidence rate in the last decade, suggesting that further investigation of these batches may assist in the identification of additional contributing factors, and/or the development of fire safety solutions.

Safety interventions

Fire safety initiatives and interventions implemented in the past decade are estimated to have saved NSW approximately $15.5 million through avoided incidents and reduced severity. These interventions are also projected to save NSW an additional $19.9 million over the next decade (2023-2032). However, with significant increase in bus fire and thermal incidence rates in recent years, OTSI analysed the efficiency of existing interventions and found several areas for improvement. These are discussed along with OTSI's recommendations below.

Recommendations

Based on the findings of this report, OTSI makes the following recommendations:

1. Establish a national database to record all bus fire and thermal incidents, and to provide consistent bus fleet data for all states and territories.

Provided operator reporting protocols and classification systems are consistent across all states, a national database will solve three major problems. Firstly, it will provide a single source of data which will allow investigation and identification of many more potential contributing factors. Secondly, a much larger dataset (e.g., than just NSW) will improve statistical relevance of diagnostic data analyses and certainty of the identified potential contributing factors. Finally, it will allow accurate benchmarking across Australia and against other countries which can assist in informing policy decisions and improving bus fire safety through identification of potentially unique causes of fire, and shared bus fire safety learnings.

For open and transparent research and analysis, it is recommended that this database be made available publicly. Further, it is recommended that data classifications in this database be considered carefully so that information on causes and potential contributing factors identified in this report is captured, along with information on other factors such as fuel type, type of emission control technology, type of fire mitigation technology, bus type, route, bus load, and bus maintenance and servicing schedules.

2. Review the average age and age distribution of the NSW bus fleet.

With identified correlation between bus age and bus fire and thermal incidence rates, and likely correlation between bus age and severity of damage sustained by the bus involved in a fire, OTSI recommends that the average age of the NSW bus fleet be reviewed. The bus fleet analysis has shown that the number of new bus deliveries to NSW has been decreasing since 2018, resulting in an increase in the average age of the NSW bus fleet in the last few years. The average NSW bus fleet age (for buses registered as heavy vehicles) in 2022 was 12.2 years – highest in the last decade.

Further, bus fleet age distribution analysis has shown that new bus deliveries in NSW have varied significantly over the years. A major delivery of new buses in a year was followed by much fewer new bus deliveries in the subsequent years. This has resulted in big clusters of buses of a particular age group. As these clusters age, the likelihood of the bus fire and thermal incident increases. Therefore, it may be beneficial to review the purchasing patterns and adopt a more consistent approach to maintain a regular delivery of new buses.

3. Review existing fire and smoke detection technologies in buses and explore newer solutions that can lead to early fire detection.

In the last decade, only ~6% of bus fire and thermal incidents were detected by fire alarms and/or smoke detectors. Further, in buses fitted with tyre monitoring systems, 20% of bus fires and 19% of thermals originating in the wheel well area of the bus activated the tyre monitoring systems. These findings highlight the need to review existing fire and smoke detection technologies in buses and to explore newer solutions that can lead to early fire detection. Early fire detection can allow quicker implementation of fire mitigation solutions, leading to lower risk to passengers and reduced damage to buses.

4. Review the appropriateness of the type, location, installation and maintenance of the existing fire mitigation/fighting technologies fitted in the buses, while ensuring rigorous risk assessment and regular audits for compliance.

OTSI has identified deficiencies in the implementation or use of existing fire mitigation technologies fitted in the buses. In buses equipped with EBFSS, only 56% of fires and 9% of thermal incidents originating in the engine bay in the last decade activated the fitted EBFSS. Also, engine bay is still the most dominant area of origin for bus fires. These findings suggest the need to review the threshold for the activation of EBFSS, along with their design, installation, location, and maintenance.

It was also found that the percentage of bus fires where the response included use of a portable onboard fire extinguisher has declined over the years. Of the incidents where a fire extinguisher was used, the success rate of the extinguisher has also declined over the years. These trends suggest the need to review the appropriateness of the type of extinguisher and its location on the bus, along with the sufficiency of driver training into the use of onboard extinguishers.

5. Explore additional fire mitigation/fighting technologies for bus fire safety.

Considering the deficiencies in existing fire mitigation technologies, and that ~40% of the bus fires in the last decade originated in the body or wheel well of the bus where no automatic fire suppression systems are fitted, it is recommended that additional fire mitigation technologies be explored.

Newer technologies are also required to proactively maintain fire safety in the new zero-emission electric and hydrogen powered buses.

6. Review Australian Design Rules and TfNSW procurement panels for buses.

The Australian Design Rules do not currently mandate automatic fire suppression systems in buses (including coaches). While TfNSW procurement panels require EBFSS, they do not require suppression systems in other areas of the bus at risk of fire such as the body or wheel well. These factors pose a risk to passenger safety, especially considering the recent increase in the percentage of body or wheel well originated bus fires. Moreover, coaches without EBFSS and with only one entry or exit door pose an even higher risk to passengers in the event of a fire.

In addition, previous OTSI bus fire incident investigations have highlighted concerns about the flammability of bus materials and the adequacy of required fire extinguishers under the Australian Design Rules. It is recommended to investigate these factors, assess the risks involved, and review the standards, TfNSW procurement panels, and Australian Design Rules based on the findings.

Areas for further investigation

In addition to the areas highlighted in the findings and recommendations that require further investigation, this report has identified the following areas for further investigation or research to improve bus fire safety.

Significant differences in bus fire and thermal incidence rates were found between NSW and other Australian states, and NSW and England. Within Australia, and among states which shared their data with OTSI and agreed for their data to be included in this report, NSW had most bus fires per 10,000 buses in 2022. Further investigation into the differences in incidence rates, along with a comparison of bus fleet, road congestion and average bus loads may allow the identification of new, and/or validation of already identified potential contributing factors to bus fire and thermal incidents.

Incident time analysis and benchmarking analysis have indicated the possibility of a correlation between bus load or road congestion and bus fire/thermal incidence rate. The highest bus fire and thermal incidence rates (normalised to the number of Opal bus trips) were found to be in the peak travel times. In addition, NSW's bus fire incidence rates normalised to the number of buses were found to be consistently and significantly lower than in England over the last decade. However, incidence rates were found to be comparable when considered per 100M bus passenger trips, thus highlighting that England's buses have a significantly higher bus load and correspondingly higher fire incidence rate per bus compared to NSW. Further investigation is required to verify the correlation between bus load/congestion and the likelihood of a bus fire/thermal incident. If confirmed, an investigation into understanding the mechanical basis behind this correlation may lead to the development of potent fire mitigation solutions.

Asset inspection, maintenance and assurance are essential preventative measures of an asset management maturity framework. Considering this report has found that fire and thermal incidence rates increase with bus age, the appropriateness of the frequency and quality of these preventative measures needs to be investigated.

Several other factors, such as fuel type, bus load, type of emission control technology, and road congestion should also be investigated as potential contributing factors to bus fire and thermal incidents. No baseline data could be obtained for these categories which prevented data normalisation and diagnostic analyses in this report.

Comparative analysis between the effectiveness of different types of EBFSS in detecting and suppressing fires could not be performed in this report due to data limitations. Similarly, improvement in bus fire safety could not be compared between different TfNSW Bus Procurement Panels due to limited incident data on buses procured under Procurement Panels 2 and 3. As more data becomes available, these comparative analyses should be performed to understand the effectiveness of the bus fire safety initiatives undertaken by TfNSW, and to help inform policy decisions and Recommendations 4 and 6.

Further research is required to understand the fire safety risks of electric batteries, and hydrogen fuel cells, to proactively explore fire prevention, detection, and mitigation solutions for the new zero-emission buses.

Contents

Introduction

Safe and timely operation of the NSW bus network is vital for the social and economic success of the state and its people. Bus fire and thermal incidents disrupt this network and pose a significant threat to passenger and driver safety, resulting in substantial economic and social costs to the community.

In 2013, the Office of Transport Safety Investigations (OTSI) published a report which investigated the causes and circumstances of bus and coach fires in NSW from 2005 to 2012. Since then, OTSI has conducted 25 comprehensive bus fire and thermal incident investigations issuing 70 recommendations for bus fire safety improvement. In addition, OTSI has been publishing annual bus fire safety reports to continuously monitor the extent, origins and causes of bus fire and thermal incidents in NSW. This year marks the decadal anniversary of these reports.

This tenth anniversary bus fire safety report provides a detailed analysis of bus fire and thermal incidents over the last decade (i.e. 2013-2022), and provides an overview of the 2022 data. The primary objectives of this report are to 1) highlight the health, social and economic impacts of bus fire and thermal incidents in NSW, 2) investigate the causes and potential contributing factors to these incidents, 3) review the effectiveness of existing fire safety interventions, 4) emphasise the need for further improvement in bus fire safety through predictive modelling and benchmark analysis, and finally 5) make recommendations for bus fire safety improvement based on the available evidence.

The structure of the report is as follows. This introductory section is followed by the '2022 at a glance' section which provides an infographic of bus fire and thermal incidents in 2022, along with the origins, causes, damage levels, injuries and fatalities of the incidents. This infographic provides the information that is typically included in OTSI's past annual bus fire safety reports.

The next two sections, 'Bus fleet – setting the baseline' and 'Bus fire and thermal incidents', present the scale of the problem by analysing the decadal trends of bus fire and thermal incidents in NSW, and normalising them against the size, kilometrage and patronage of the NSW bus fleet. The following section, 'Measuring the impact', highlights the severity of the problem by estimating the health, social and economic impacts of bus fire and thermal incidents in the last decade. This section also highlights the need for further improvement in bus fire safety by projecting bus fire and thermal incidents and the associated costs over the next decade through predictive modelling.

The 'Origins and causes' and 'Potential contributing factors' sections investigate the causal and potential contributing factors to bus fire and thermal incidents, and answers some key questions such as 'Are older buses more likely to have a fire or thermal incident?' and 'Are buses more likely to have a fire or thermal incident in hotter weather conditions?'.

The 'Fire safety interventions' section provides estimates of the cost savings that existing interventions have brought to NSW and reviews the efficiency of engine bay fire suppression systems, tyre monitoring systems and portable fire extinguishers through analyses of their activations, use, and performance in detecting/mitigating fires.

The 'Benchmarking NSW' section compares the NSW incidence rates against national and international evidence and highlights the need for open and transparent data collection and sharing. This report concludes by making recommendations on bus fire and thermal safety improvement in the 'Recommendations' section, followed by a summary of the report and a discussion of areas for further investigation in the 'Conclusions and future work' section.

2022 at a glance
Bus fires and thermal incidents

157 Notified incidents

17 Bus fires
An 89% increase from 2021

140 Thermal incidents
A 46% increase from 2021

NSW bus fleet

950+	Accredited bus operators
13,000+	Registered buses
170 M+	Opal bus trips
210 M+	Scheduled kilometers

16
Fire & Rescue attendances

0
Injuries

OTSI actions

4	Investigations commenced
3	Investigation reports published
2	Safety advisories issued
4	Deployments

Cost to NSW

in direct, indirect and congestion delays

$34.8 M

404,000 hours

Fire incidents

Damage

- Destroyed – 2 (11.8%)
- Major – 3 (17.6%)
- Minor – 12 (70.6%)

Origins

- Wheel well – 6 (35.3%)
- Engine bay – 8 (47.1%)
- Body – 3 (17.6%)

Cause

- Brakes – 6 (35.3%)
- Mechanical – 3 (17.6%)
- Electrical – 4 (23.5%)
- Fluid – 4 (23.5%)

Method of detection

- Bus driver – 16 (94.1%)
- Others – 1 (5.9%)

Thermal incidents

Damage

- Minor – 38 (27.1%)
- NIL – 102 (72.9%)

Origins

- Wheel well – 79 (56.4%)
- Engine bay – 48 (34.3%)
- Body – 13 (9.3%)

Cause

- Brakes – 75 (53.6%)
- Mechanical – 47 (33.6%)
- Electrical – 16 (11.4%)
- Fluid – 2 (1.4%)

Method of detection

- Bus driver – 135 (96.4%)
- Others – 5 (3.6%)

Bus fleet – setting the baseline

Understanding the size, patronage and kilometrage of the NSW bus fleet is important for analysing bus fire and thermal incidents. This section describes how the NSW bus fleet has evolved over the last decade.

NSW bus fleet

Figure 1 shows a decadal comparison of the total number of registered buses (as heavy vehicles) in NSW.[1] Evidently, the NSW bus fleet steadily increased until 2019. Following the COVID-19 outbreak in NSW in early 2020 and the two associated lockdowns in 2020 and 2021, there was a significant reduction in the bus fleet in the 2020-2021 period. Although there was a slight recovery in 2022, the number of registered buses in 2022 remained much lower than the pre-COVID levels.

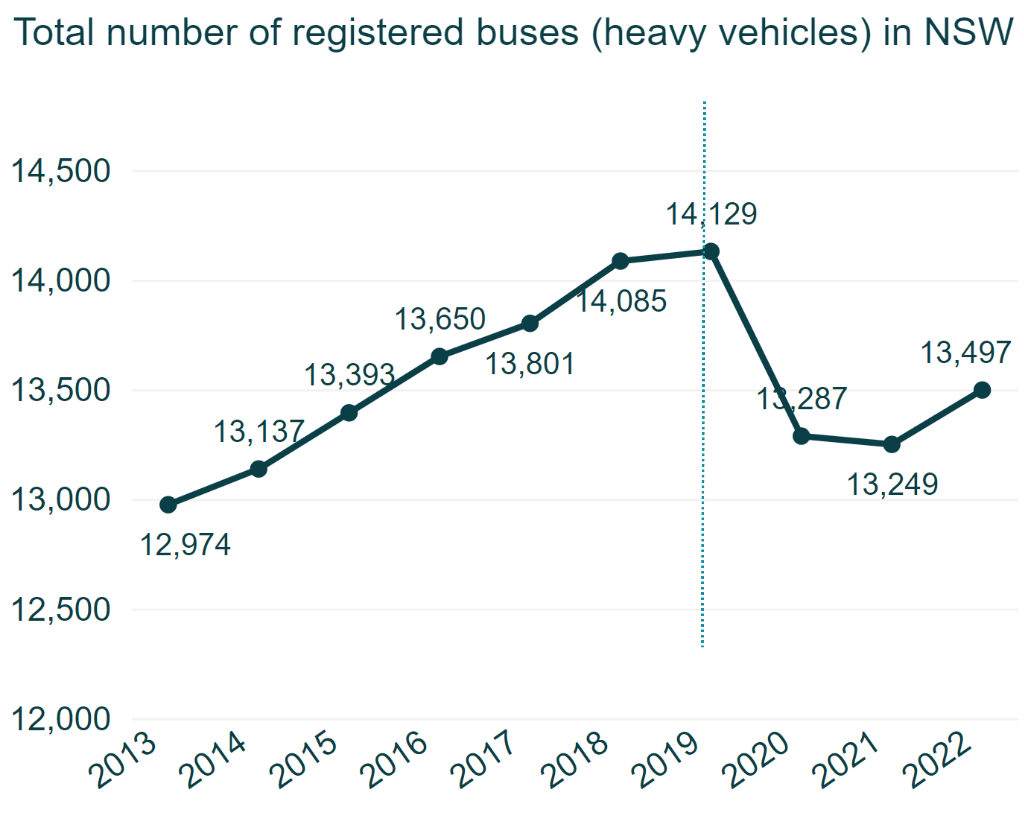

Figure 1: A decadal comparison of the number of registered buses in NSW (under heavy vehicles category).[1] Note that the numbers in this graph are based on the snapshots obtained in December of each year. The dotted line indicates the COVID-19 outbreak in NSW.

[1]NSW registrations data from Jan 2013 – Jun 2022 was obtained from https://roads-waterways.transport.nsw.gov.au/about/corporate-publications/statistics/registrationandlicensing/tables/table111.html. The numbers used in this report are for heavy vehicles → buses category, and the snapshots from December were used for all years. Post Jun 2022 data was obtained from https://www.transport.nsw.gov.au/data-and-research/drives-reporting-portal/registration-snapshot-report (by selecting “heavy vehicles” and “bus” shape type).

To supplement the registrations data, OTSI also analysed bus sales data from the Australasian Bus and Coach publications.[2] As shown in Figure 2a, the number of new buses delivered to NSW annually has been decreasing since 2018. In fact, **NSW received ~41% fewer new buses in 2022 than it did a decade ago.** The decreasing trend in new bus deliveries prompted OTSI to examine its impact on the age of the NSW bus fleet. As shown in Figure 2b, the average bus age in NSW[3] was found to remain relatively unchanged from 2013-2019. However, a rapid increase was observed post 2020, with **2022 having the highest average bus age in the last decade**.

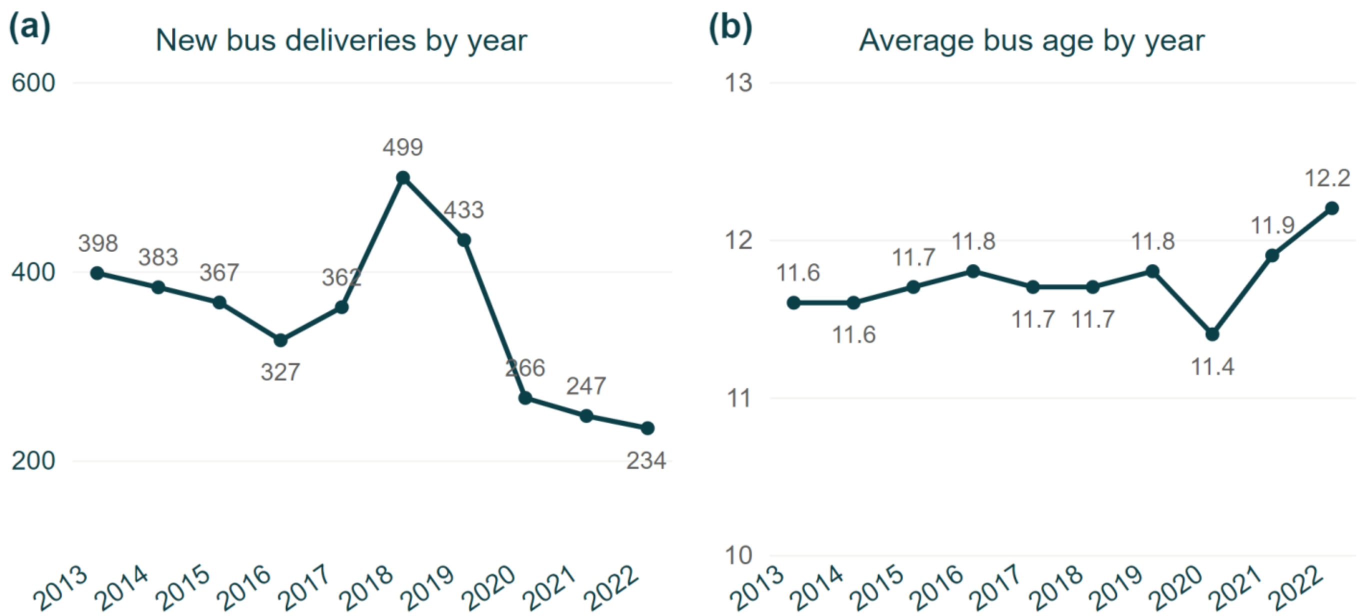

Figure 2: **(a)** The number of new bus deliveries that NSW has received every year, based on the bus sales data from Australasian Bus and Coach publications,[2] and **(b)** average bus (heavy vehicles) age (in years) calculated from the NSW registrations data for heavy vehicle buses.

To get a better understanding of NSW bus fleet's ageing and the patterns of new bus deliveries, OTSI also examined how the fleet's age distribution has changed over the last decade (i.e., how many buses were how old in a particular year). As shown in Figure 3, although the average bus age stayed largely same between 2013-2020, the actual age distributions of the bus fleet varied significantly. In 2013, the largest number of buses were 3 and 4 years old, suggesting that there had been a major delivery of new buses in 2009-10. As the fleet aged, this cluster kept on moving to ~10-11 years old. No new cluster appeared until 2018, when there was a sharp increase in the number of new bus deliveries in NSW, in line with the bus sales data (Figure 2). Similarly, the age distribution shapes indicate that **in years 2020-22, NSW had the lowest number of new buses compared to previous years.**

[2] https://www.busnews.com.au/bus-sales-data/data (accessed on 07 March 2023).

[3] Average bus age was calculated from the NSW registrations data for heavy vehicle buses from https://roads-waterways.transport.nsw.gov.au/cgi-bin/index.cgi?fuseaction=statstables.show&cat=Registration. For calculation of the average age, a bus manufactured in 2020 was assumed to be 0 years old in 2020, 1 year old in 2021 and so on. Also, since the year of manufacture dataset was only available until June 2022, June snapshots were used for the calculation of the average bus fleet age for all years, to allow accurate comparison between years. For all other age-related analyses in this report, December snapshots have been used for years 2013-2021, and June snapshot has been used for 2022.

Note: *Bus fleet data was available from multiple sources, including from Transport for NSW (TfNSW) contracted buses database, NSW registrations data,[1] Australian Bureau of Statistics (ABS),[4] and the Bureau of Infrastructure and Transport Research Economics (BITRE).[5] However, for consistency and accuracy, especially while comparing data across years, all the baseline data (i.e. total number of buses and their age distributions) needed to be available from a single source for the entirety of 2013-2022, and needed to include majority of the buses that report fire and thermal incidents to OTSI. Considering these stipulations, data based on NSW registrations has been used for normalisation in most of this report. Datasets from ABS and/or BITRE have only been used where comparisons between different states or countries were required for selected years, and this has been clearly stated in those sections.*

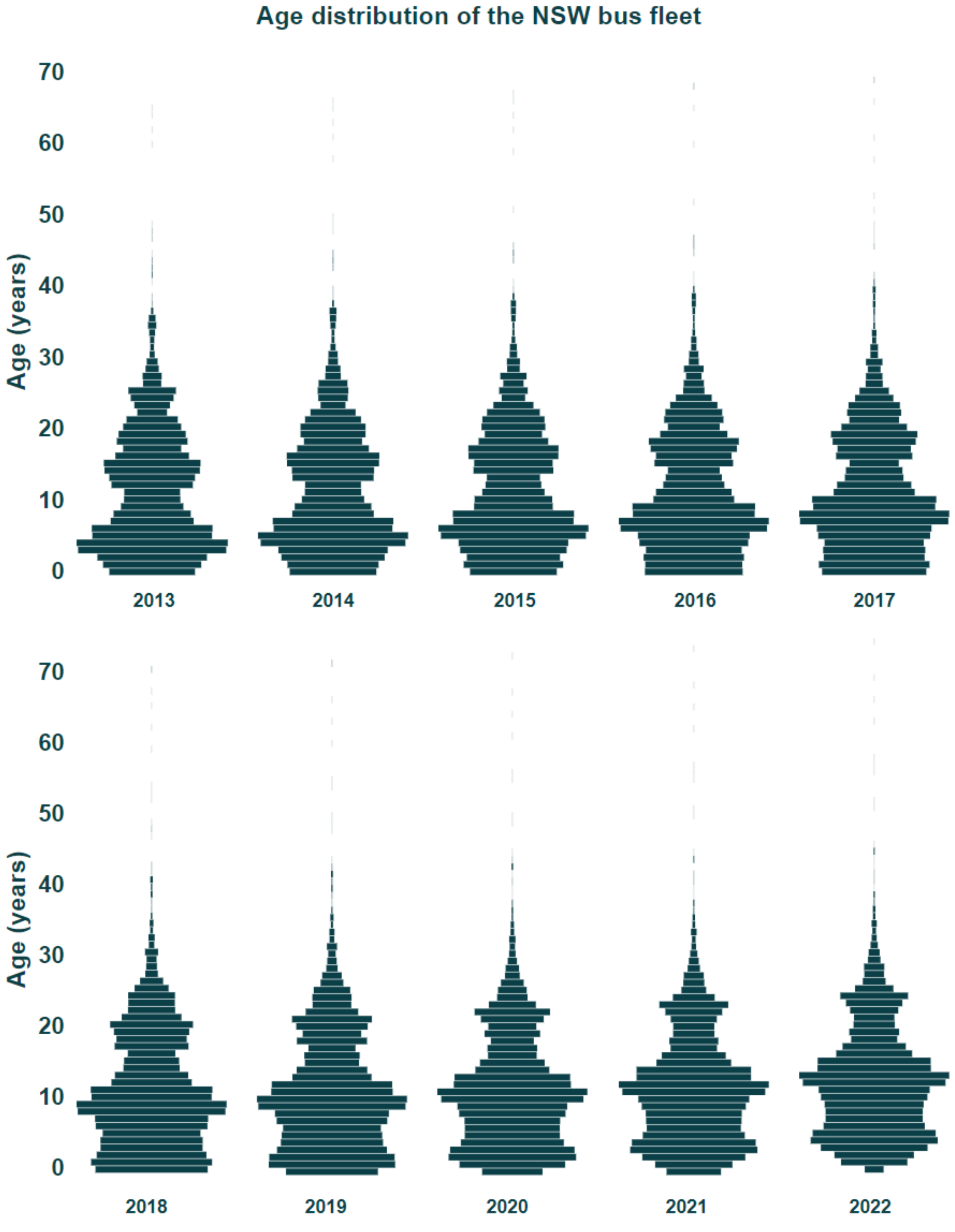

Figure 3: Decadal comparison of the age distributions of the NSW bus fleet (registered as heavy vehicle buses). The longest horizontal bar in every distribution represents ~900 buses.

[4] https://www.abs.gov.au/statistics/industry/tourism-and-transport/motor-vehicle-census-australia (accessed on 12 April 2023)

[5] Bureau of Infrastructure and Transport Research Economics (BITRE) 2022, Motor Vehicles, Australia, January 2022 (First Issue), BITRE, Canberra, Australia. https://www.bitre.gov.au/sites/default/files/documents/BITRE-Motor-Vehicles-Australia-2022-FirstIssue.pdf (accessed on 12 April 2023)

Bus kilometrage and patronage

Kilometrage[6] and patronage[7] data for NSW buses is shown in Figure 4. Bus patronage data closely follows the trend observed for the number of registered buses (Figure 1a), where a steady increase until 2019 was followed by a significant drop in 2020-21 with a slight recovery in 2022. The trend in scheduled bus kilometrage data was found to be different. Barring a drop in 2021, scheduled bus kilometrage was found to have consistently increased over the last decade, and by 2022, had already recovered to pre-COVID levels.

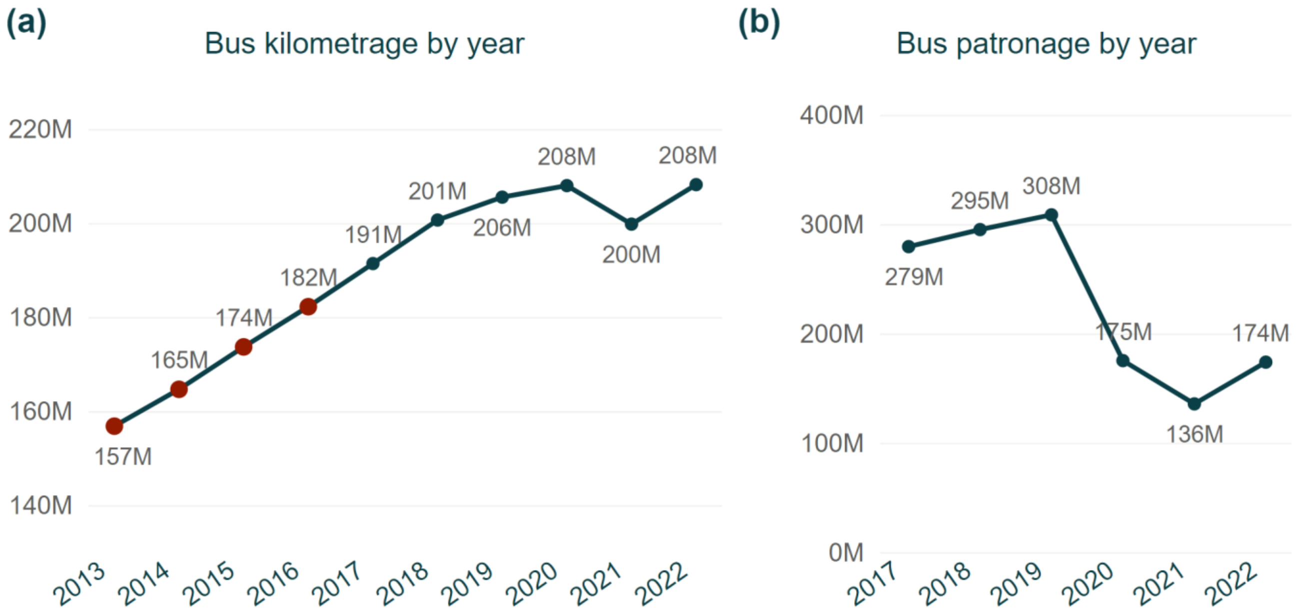

Figure 4: (a) Bus kilometrage and (b) patronage data for NSW. Red circles indicate that the data for years 2013-2016 includes some estimations based on the extrapolation of the trends from 2017-2019. Patronage data is based on the Opal card trips which was only available from July 2016 onwards.

The decreasing numbers of new bus deliveries and registered buses, combined with an increasing trend in bus kilometrage (albeit only for metro and outer metro contracts), suggests a continuous increase in the average number of kilometres travelled by NSW buses annually. Since, the kilometrage data included metropolitan and outer metropolitan contracts only, whereas the bus fleet data included all registered heavy vehicle buses in NSW, OTSI has not quantified the average kilometres travelled per bus based on these two datasets.

The decadal comparison of the fleet numbers, patronage and kilometrage of NSW buses allowed OTSI to find an appropriate denominator to use to normalise the incident data so that valid comparisons between the years could be made. Data normalisation also removed biases and allowed exploration and identification of causes and potential contributing factors through statistical analyses of the incidental data.

[6] The kilometrage data was obtained from TfNSW and only includes scheduled kilometres for the Sydney metropolitan and outer metropolitan bus contracts. No data could be obtained for the regional and rural contracted buses. Also, the kilometrage data for the years 2013-2016 was incomplete for some contracts. Therefore, data for these years includes estimations based on the extrapolation of the trends for different contract types in 2017-2019.

[7] Bus patronage data is based on opal card bus trips available from https://opendata.transport.nsw.gov.au/dataset/opal-trips-bus from July 2016 onwards.

Bus fire and thermal incidents

OTSI receives notifications of bus fire and thermal incidents in NSW under the *Passenger Transport Act 1990 (NSW)*. **In the last decade (2013-2022), OTSI recorded a total of 816 notifications including 177 bus fires and 639 bus thermal incidents in NSW.** Note that these notifications do not include incidents that were initially reported as a fire/thermal incident, but later found to have no flames and no potential for the incident to result in a fire (see 'Appendix A – Glossary' for definitions).

As shown in Figure 5, the number of bus fires in NSW has been increasing since 2019, with an 89% jump in 2022 compared to 2021. This contrasts with the 2016-2019 trend where a significant reduction in the number of bus fire incidents was observed.

The bus thermal incidence rate was found to increase every year since 2013, barring a drop in 2020. 2022 recorded most bus thermal incidents on record for NSW.

***Note**: For this report, OTSI competed a data cleansing process for all the data captured by OTSI since 2013. This resulted in the reclassification of some bus fire and thermal incidents. Consequently, the data in this report is different to that reported in earlier annual bus fire safety reports, with most changes primarily in the years 2013-2015.*

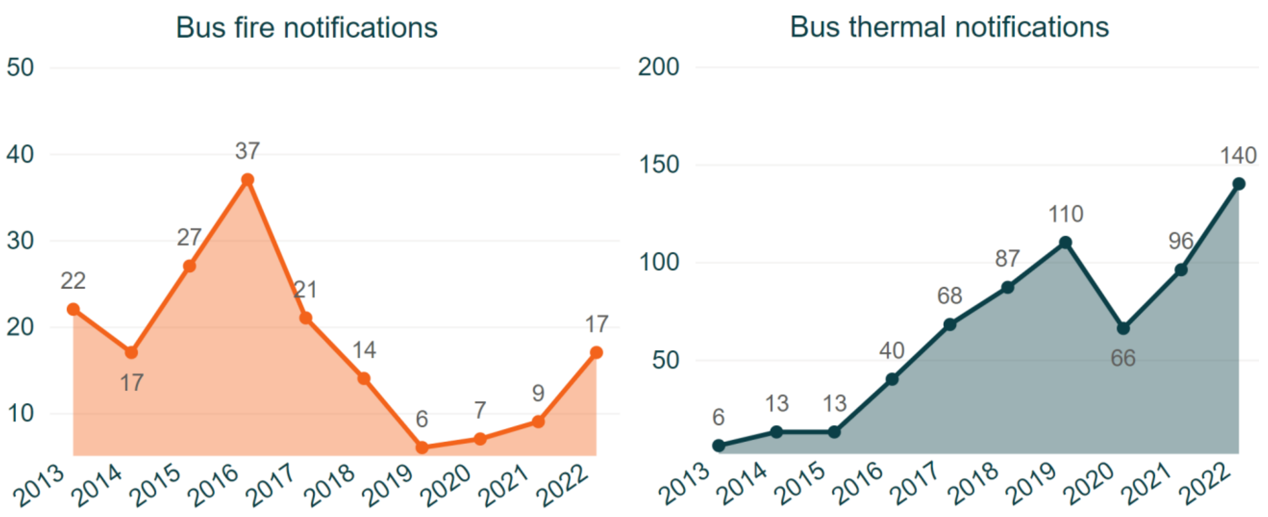

Figure 5: The decadal comparison of the number of bus fire and thermal incident notifications received by OTSI under the Passenger Transport Act 1990 (NSW). Note that OTSI completed a data cleansing process for all data captured by OTSI since 2013. This resulted in the reclassification of some bus fire and thermal incidents, with most changes primarily in the years 2013-2015.

To remove any bias, and to explore actual trends, fire and thermal incident data was normalised against the number of registered buses (as heavy vehicles) in NSW (Figure 1), the kilometres travelled by metropolitan and outer metropolitan buses (Figure 4a) and the number of bus Opal trips (Figure 4b). All normalised data, shown in Figure 6, confirm the **increasing trends for both fire and thermal incidents, with 2022 having the highest number of bus thermal incidents ever**.

Origins, causes and potential contributing factors behind the increase in bus fire and thermal incidence rates are explored and discussed in the 'Origins and causes' and 'Potential contributing factors' sections. The following section measures the health, social and economic impacts of bus fire and thermal incidents in the last decade to highlight their severity.

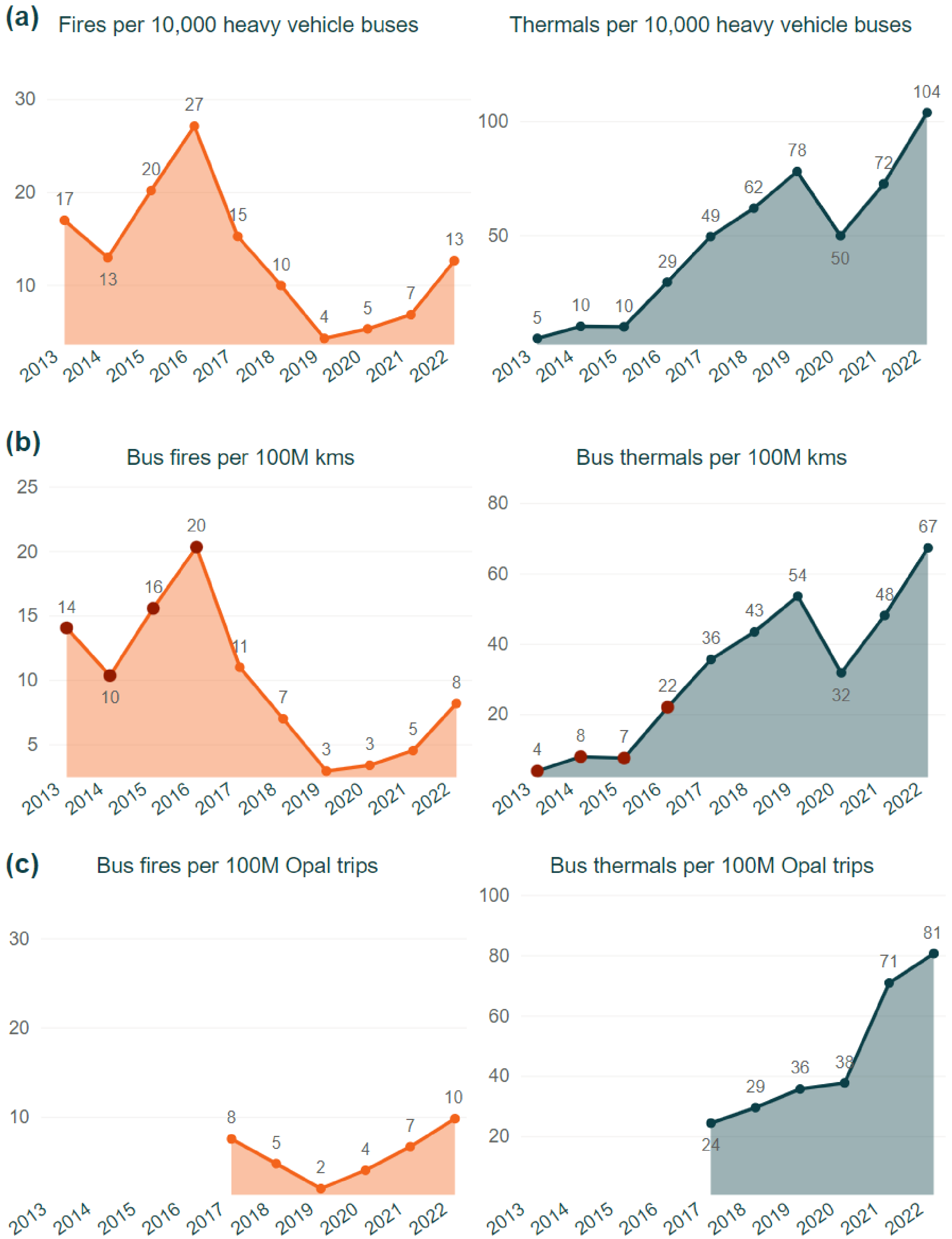

Figure 6: Bus fire and thermal incident notifications normalised to **(a)** NSW bus fleet (heavy vehicle buses), **(b)** bus kilometrage (metro and outer metro) and **(c)** bus patronage. The red circles highlight that kilometrage data for these years included estimations. For data sources, caveats and limitations, please see sections **NSW bus fleet** and **Bus kilometrage and patronage**.

Measuring the impact

Bus fire and thermal incidents have the potential to substantially impact the NSW community through harm and injury to the bus driver and passengers onboard, damage to vehicles and property, and the flow-on impacts of disruption to passengers across the bus network and to road users. This section presents a measure of the impact that bus fire and thermal incidents in NSW have had over the last decade.

Physical injuries

Of the 816 bus fire and thermal incidents reported in the last 10 years, **466 incidents had passengers on board the bus at the time of the incident** (Figure 7a). The relative distribution of incidents with passengers on board was found to be similar for bus fires (~62% of the bus fires had passengers on board) and bus thermals (~56% of the thermals had passengers onboard). Of the 466 incidents passengers were on board, 266 incidents had 1-10 passengers, 94 incidents had 11-20 passengers, and 106 incidents had >20 passengers at the time of the incident (Figure 7b).

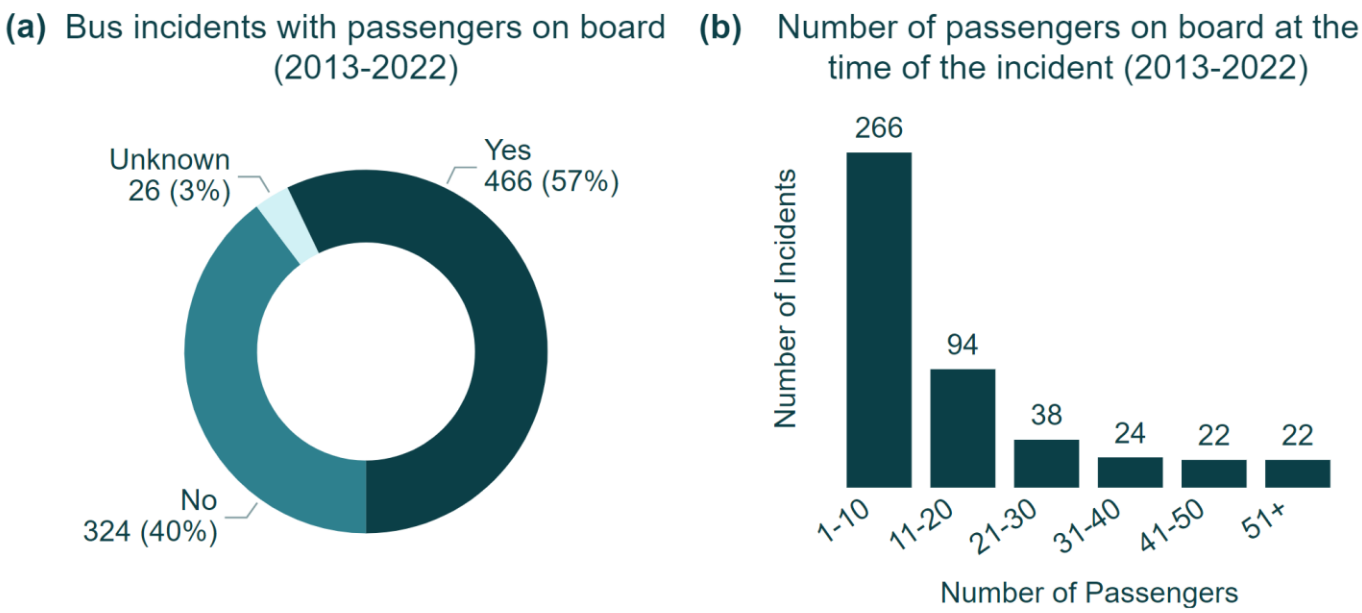

Figure 7: (a) The number of bus fire and thermal incidents in the last 10 years which had passengers on board at the time of the incident. **(b)** The distribution to show how many incidents had how many passengers on board at the time of the incident.

Regardless of the large number of incidents with passengers on board, **there were no reported fatalities due to bus fire and thermal incidents in NSW in the last 10 years.** Further, only **4 incidents led to injuries to passengers or drivers** (Figure 8). This suggests that 1) most fire and thermal incidents have likely occurred in an area of the bus which has not restricted egress, 2) fire suppression systems have likely been effective, providing more time for evacuation, and/or 3) passenger evacuation has likely been appropriate and effective. All these hypotheses are examined in greater detail later in the report.

Of the 4 incidents that resulted in injury, three were due to bus fires and one was due to a bus thermal. Each of the 4 incidents had one injury, with all injuries reported as minor – three were due to smoke inhalation and one was from a sprained ankle while alighting the bus.

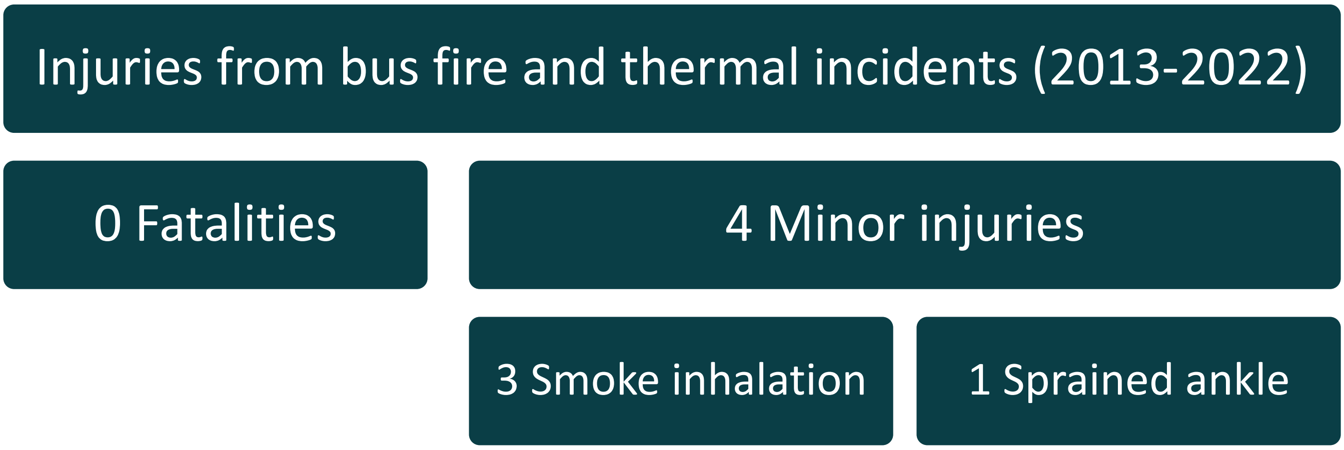

Figure 8: Summary of the number of injuries in from the bus fire and thermal incidents from 2013-2022.

Psychological impact

It is easy to ignore, and difficult to measure the psychological impact of bus fire and thermal incidents on the people involved – be it drivers, passengers on board, emergency workers or bystanders. There is also limited literature on the mental health consequences of bus (or public transport) fires on those directly involved in the incident.

However, there is overwhelming evidence of the psychological impact of fire-related trauma,[8] and traffic crashes[9] on people. It is also known that fire-fighters suffer from high rates of mental health conditions, with rates of depression and post-traumatic stress disorders (PTSD) increasing with each additional trauma exposure.[10] Finally, studies have also indicated that bus drivers have poorer mental health compared to general population.[11]

This section aims to increase awareness of the potential for psychological injuries arising from bus fire and thermal incidents, even though they are not captured in the usual databases. As part of incident investigations, OTSI has interviewed many drivers involved in major bus fire and thermal incidents over the last decade. A search through the interview transcripts and recordings shows that drivers reported that they 'experienced anxiety' and had 'trouble sleeping' after the incident. In some incidents, drivers reported fearing that the bus would explode, further adding to their trauma. In a particular incident, the driver said that when the bus fire broke out, they thought that 'it was a bomb'. This driver retired from driving public buses after the incident.

---

[8] Laugharne, J., Van de Watt, G., & Janca, A. (2011). After the fire: the mental health consequences of fire disasters. *Current Opinion in Psychiatry*, *24*(1), 72-77.

[9] Fitzharris, M., Fildes, B., & Charlton, J. (2006). Anxiety, acute-and post-traumatic stress symptoms following involvement in traffic crashes. In *Annual Proceedings/Association for the Advancement of Automotive Medicine* (Vol. 50, p. 297).

[10] Harvey, S. B., Milligan-Saville, J. S., Paterson, H. M., Harkness, E. L., Marsh, A. M., Dobson, M., ... & Bryant, R. A. (2016). The mental health of fire-fighters: An examination of the impact of repeated trauma exposure. *Australian & New Zealand Journal of Psychiatry*, *50*(7), 649-658.

[11] John, L. M., Flin, R., & Mearns, K. (2006). Bus driver well-being review: 50 years of research. *Transportation Research Part F: Traffic Psychology and Behaviour*, *9*(2), 89-114.

This evidence from OTSI's investigations, combined with other studies highlight the incidental psychological health effects of bus fire and thermal incidents on bus drivers; an area that would benefit from further study.

Property damage

OTSI classifies damage caused to buses due to fire or thermal incidents into five categories: destroyed, major, minor, smoke and nil damage. These category definitions are described in 'Appendix B – Severity level descriptions for bus damage'.

Figure 9 shows the overall distribution and the year-by-year breakdown of how many buses sustained what level of damage because of fire and thermal incidents over the last decade. The data shows that a vast majority (~94%) of fire and thermal incidents over the last 10 years caused minor, smoke or no damage to the bus. However, even with only ~6% of buses sustaining major damage or above, there were **31 destroyed buses and 21 buses with major damage in NSW, equating to over 5 buses requiring major repairs or replacement every year, on average, due to bus fires**.

Note*: As is clear from the year-by-year distribution in Figure 9, classification of damage levels has been inconsistent over the years. In some years, OTSI included smoke damage as a separate classification, whereas in others, smoke damage was combined with the nil damage category. For consistency, smoke and nil damage categories will be combined from 2023 onwards.*

The year-by-year breakdown shows that although the number of fires increased from 9 in 2021 to 17 in 2022, the number of buses with major damage or above was about the same. This suggests that most of the observed increase in bus fires resulted in only minor damage to the bus. Similarly, although the number of thermal incidents has been increasing at a rapid rate, most incidents resulted in no damage or only smoke damage. This also likely explains, in part, the low number of injuries (Figure 8) that NSW has had due to bus fire or thermal incidents.

A clearer understanding of the trends is presented in Figure 10 which shows the number of buses with a particular damage level in a year as a percentage of the total incidents in that year. The data confirms that an increasingly higher percentage of thermal incidents are resulting in nil or smoke damage only. This was verified statistically,[12] with the correlation coefficients indicating a moderate negative correlation for the minor damage versus year graph (correlation coefficient = -0.48) and a moderate positive correlation for the nil + smoke damage versus year graph (correlation coefficient = +0.46) for bus thermal incidents.

For bus fires, Figure 10 shows that the relative number of buses sustaining minor damage has largely stayed the same over the years. The fluctuations in the trends can be attributed to the low number of bus fires, which makes statistical analysis difficult.

[12] Statistical correlation between two datasets can be estimated through the so-called Pearson Correlation Coefficient (often simply referred to as a correlation coefficient). A positive correlation coefficient suggests that the datasets are directly correlated i.e., if one dataset (or variable) increases, the other increases as well. Negative correlation coefficient indicates an inverse relationship between the datasets. Typically, if the absolute value of the correlation coefficient is >0.8 it is assumed that there is very strong correlation between the datasets. Values of 0.6-0.8 indicates a strong correlation, 0.4-0.6 a moderate correlation, 0.2-0.4 a weak correlation, 0-0.2 a very weak correlation, and if the correlation coefficient is 0, then there is no correlation. Note that these limits and definitions are context and field-dependent but should suffice for the purposes of this report.

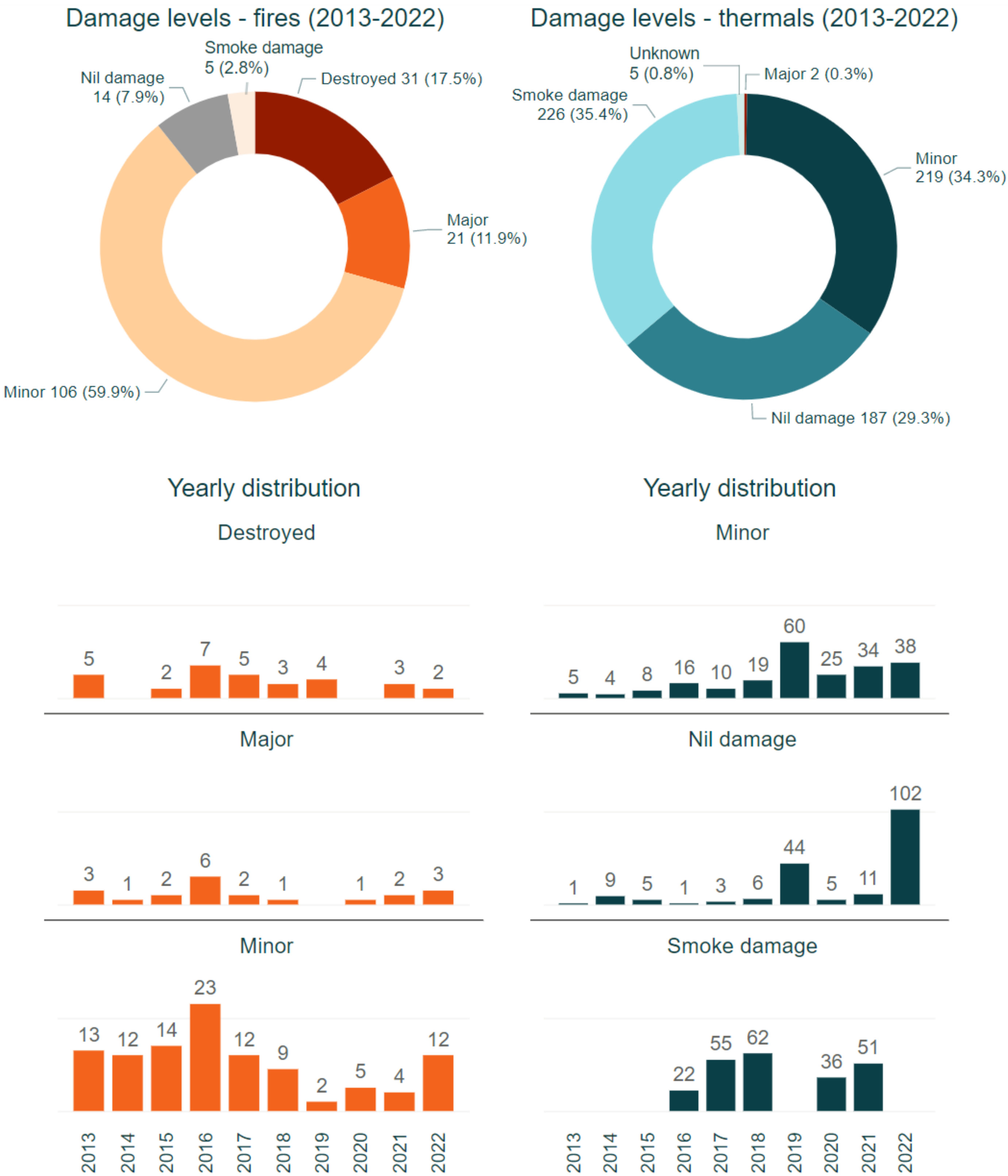

Figure 9: The overall distribution and the year-by-year breakdown of how many buses sustained what level of damage because of the fire and thermal incidents in the last decade.

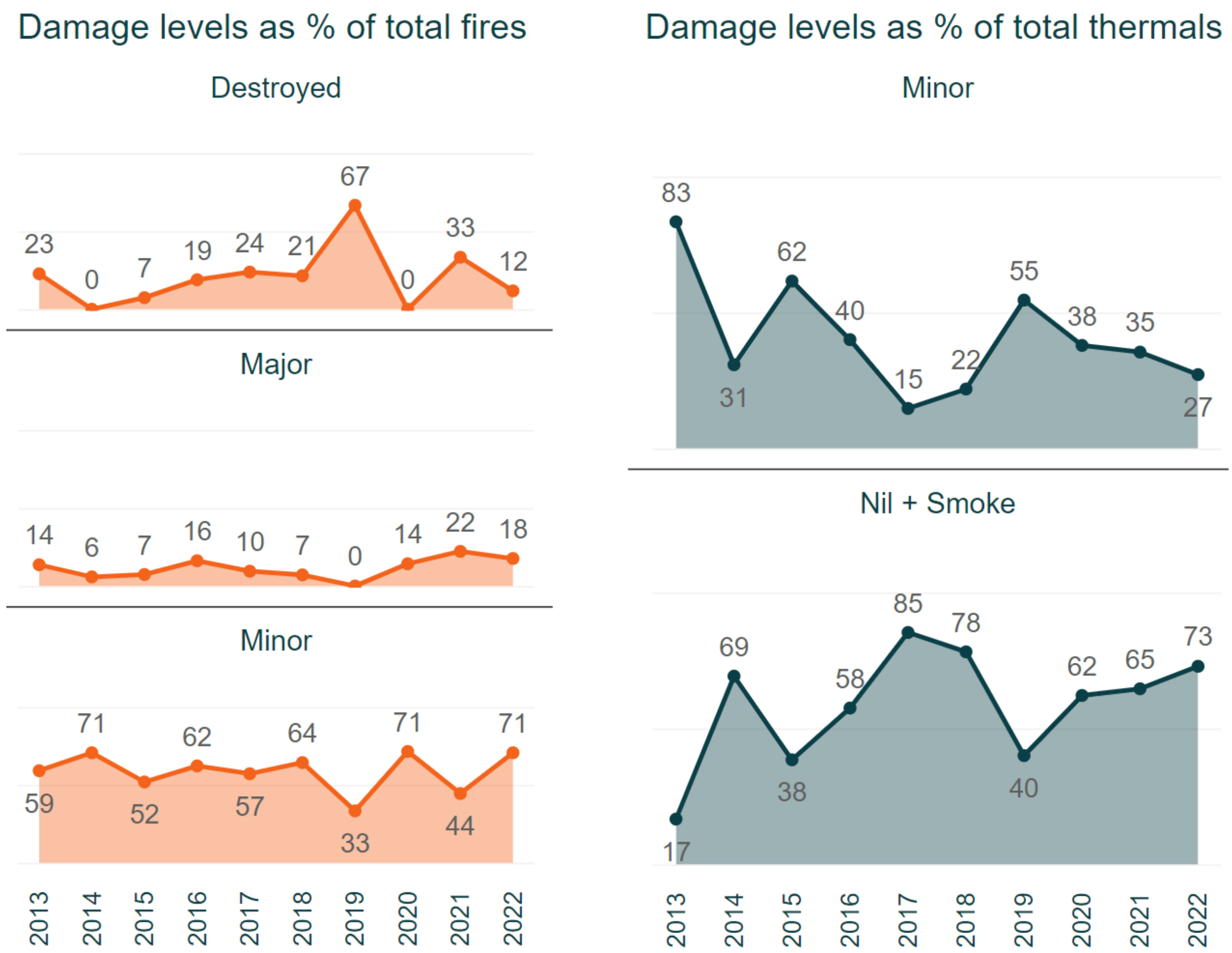

Figure 10: The number of buses that sustained a particular level of damage due to a fire or thermal incident, presented as a percentage of the total fire or thermal incidents in that year, respectively.

In addition to damaging buses, bus fire-related incidents can also cause serious damage to other property such as road infrastructure, nearby vehicles and/or buildings. OTSI does not routinely collect data on such damage which makes it difficult to classify or quantify its extent. A search through past investigation reports on bus fire incidents, however, highlighted several instances where a bus fire damaged property other than the bus. These instances included heat and smoke damage to a shopping centre, a bus shelter, nearby cars, a toll office, a university building, road, and tunnels (including jet fans) leading to expensive repairs.

In summary, the above analyses show that **despite the increase in bus fire and thermal incidence rates in recent years, the severity of damage caused to the involved bus has decreased**. However, the true impact of the incidents is likely greater and more widespread as even minor incidents have flow-on effects through disruption to passengers across the bus network and to other road users. Nevertheless, the increasing number of incident reports with no damage to the buses suggests that the existing bus fire mitigation technologies have likely been effective at reducing the severity of the incident, and at least part of the increase in incidence rates may be attributed to enhanced fire safety awareness and better reporting by bus operators.

Together, the health, property and flow-on effects of bus fire and thermal incidents result in significant economic costs to NSW. These are estimated in the section below.

Economic impact

OTSI engaged HoustonKemp, Sydney-based economists, 1) to estimate the direct and indirect economic costs incurred by NSW because of bus fire and thermal incidents over the last decade, and 2) to develop predictive models to forecast bus fire and thermal incidence rates and their associated costs for the next decade (i.e. 2023-2032), based on existing trends and assuming no further improvements in bus fire safety.

This section sets out the cost estimates and projections. Further details on the type of the costs associated with the incidents, estimation process and predictive modelling are given in 'Appendix C – Approach to the assessment of economic costs and benefits'.

Historical impact

Bus fires are estimated to have cost NSW approximately $52.4 million in present value (PV) terms (expressed in 2022 dollars). This translates to an annualised value of $6.8 million per year between 2013 and 2022, representing an average cost of almost $300,000 for each fire incident, across the 177 incidents recorded.

Figure 11 provides a breakdown of the estimated economic costs of the 177 bus fire incidents over the 10-year period into the six principal cost categories discussed in 'Appendix C – Approach to the assessment of economic costs and benefits'.

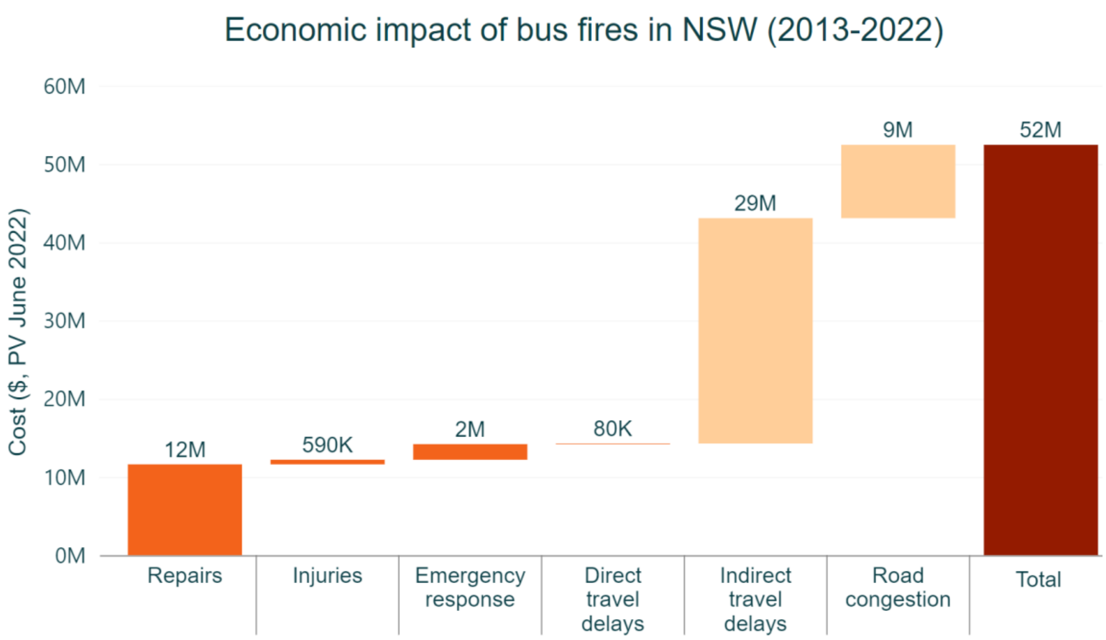

Figure 11: A breakdown of the economic impact of the bus fires in NSW between 2013 and 2022. The costs are presented in present value (PV) terms and expressed in 2022 dollars.

Nearly three quarters of the costs of bus fire incidents are estimated to be related to flow-on economic costs of indirect travel delays and congestion. Note that although the costs to downstream passengers and commuters only relate to increased journey times compared to a broader range of direct economic costs, the number of people affected compared to direct passengers is an order of magnitude larger. This larger base of downstream passengers is primarily responsible for most of the economic cost of bus fire incidents.

Direct economic costs are dominated by the costs of replacement and repair of the damaged buses. This reflects the high capital cost of bus replacement and repair, and the relatively small number of direct passengers affected by the bus fire incidents. On average, only 11 passengers were travelling on buses when a fire incident occurred. A positive observation in examining the direct economic costs is that there were no fatalities during the period between 2013 and 2022, while only a small number of injuries were observed that contributed to a low level of cost arising from physical harm.[13]

Bus thermal incidents are estimated to have cost NSW approximately $150.8 million in present value (PV) terms (expressed in 2022 dollars). This translates to an annualised value of $19.5 million each year between 2013 and 2022 which represents an average cost of $236,000 per incident across the 639 thermal incidents observed during the 10-year period.

Figure 12 provides a breakdown of the estimated economic costs of the 639 bus thermal incidents over the 10-year period.

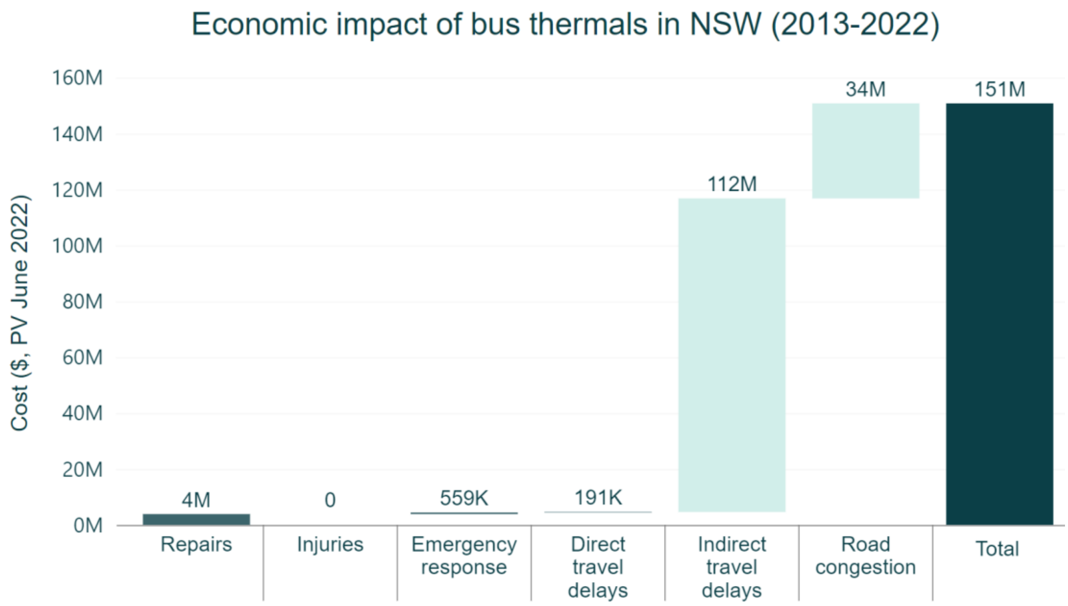

Figure 12: A breakdown of the economic impact of the bus thermal incidents in NSW between 2013 and 2022. The costs are presented in present value (PV) terms and expressed in 2022 dollars.

Nearly all the economic costs incurred from the thermal incidents are estimated to be due to flow-on effects of the indirect travel delays and congestion.

Direct economic costs were estimated to be only three per cent of the total costs. This is due to the assumption that typically, a thermal incident is unlikely to cause major damage, attract emergency services responses, or cause injuries (and fatalities). Costs from direct travel delays are also relatively low as a consequence of the limited number of passengers directly impacted by thermal incidents, as was the case for bus fire incidents.

Conversely, flow-on economic costs of thermal incidents are driven by the larger number of thermal incidents that result in delays for downstream bus passengers and commuters. Note that this effect is particularly pronounced for thermal incidents (compared to bus fire incidents) given the much larger number of these events. Congestion costs contribute to a smaller proportion of economic

[13] Assumed cost of injury for major and destroyed levels of damage is applied to observed incidents between 2013 and 2022 to derive a cost of injuries over that period.

costs, as is the case for bus fire incidents, where additional journey time for commuters can be lower on average than delays experienced by downstream bus passengers.

Projected costs

As shown in Figure 13, bus fire and thermal incidence rates are projected to keep increasing over the next ten years, unless further improvements towards bus fire safety are made. Economically, **bus fires are estimated to cost NSW $37 million, and bus thermals $228 million in present value terms from 2023-2032**.

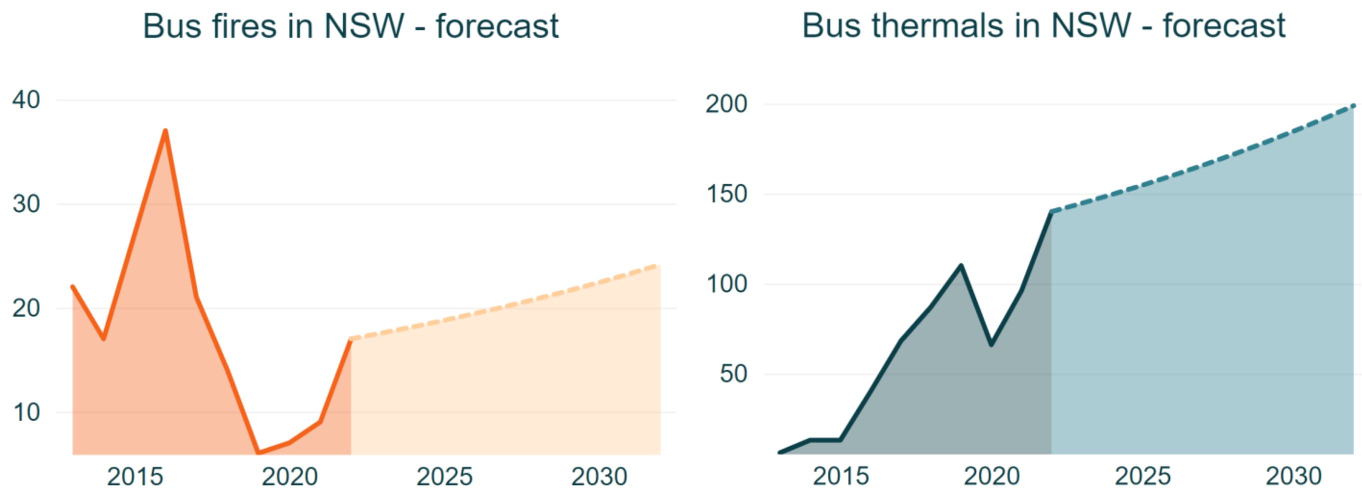

Figure 13: Historic outlook and forecast of the bus fire and thermal incidents in NSW. The forecast was estimated assuming no further improvements towards bus fire safety.

In annualised terms, the expected cost of bus fires is projected to decrease over the next decade in present value terms (this reflects the fact that although the cost of bus fires is growing, its growth rate is slower than the prevailing social discount rate). However, **the cost of thermal incidents is expected to increase from $19.5 million per year to $29.5 million per year over the next ten years** if no further improvements are made in the fire safety interventions and initiatives. This outcome is driven by an escalating rate of thermal incidents in comparison to a reduction in bus fires over the analysis period. For instance, the number of thermal incidents increased 22-fold, i.e., from 6 incidents per year to 140 incidents per year, between 2013 and 2022, while the number of bus fires decreased 23 per cent, from 22 incidents per year to 17 incidents per year, between 2013 and 2022.

Higher projected incidence rates and their associated costs, compared to their historical trends, highlight the urgent need for action to improve bus fire safety. In the following sections, the origins, causes and potential contributing factors to bus fire and thermal incidents are investigated, followed by a review of the existing fire safety interventions.

Origins and causes

Origins

For the origin of fire and thermal incidents, OTSI categorises a bus into three areas: engine bay, wheel well and body. As shown in Figure 14, **most bus fires in the last 10 years originated in the engine bay, whereas the majority of bus thermal incidents originated in the wheel well**.

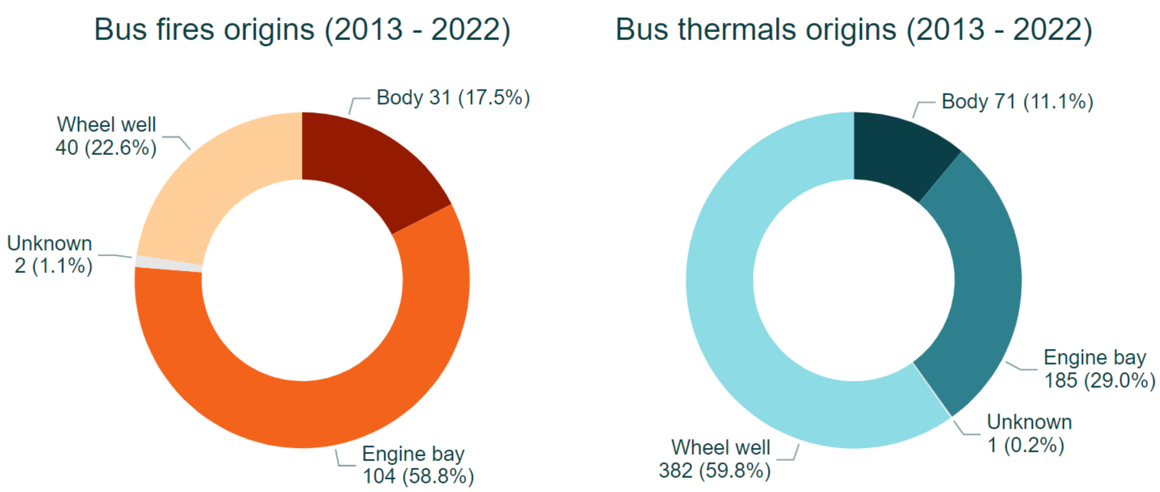

Figure 14: The overall distribution of area of the bus where fires and thermal incidents originated in the last 10 years.

The year-by-year distribution of the origin of bus fire and thermal incidents is shown in Figure 15. In line with Figure 14, the engine bay was the main area of origin for bus fires, and the wheel well was the main area of origin for bus thermal incidents, for most (but not all) years. A large part of the steep increase in the number of bus thermal incidents in 2022 from 2021 (140 from 96 incidents) was found to be due to an abrupt increase in thermals originating in the engine bay. This observation is surprising as overall only 29% of the thermal incidents originated in the engine bay over the last decade. OTSI analysis, discussed in more detail in the following section, showed that the observed increase in thermal incidents originating in the engine bay in 2022 was almost entirely due to mechanical problems.

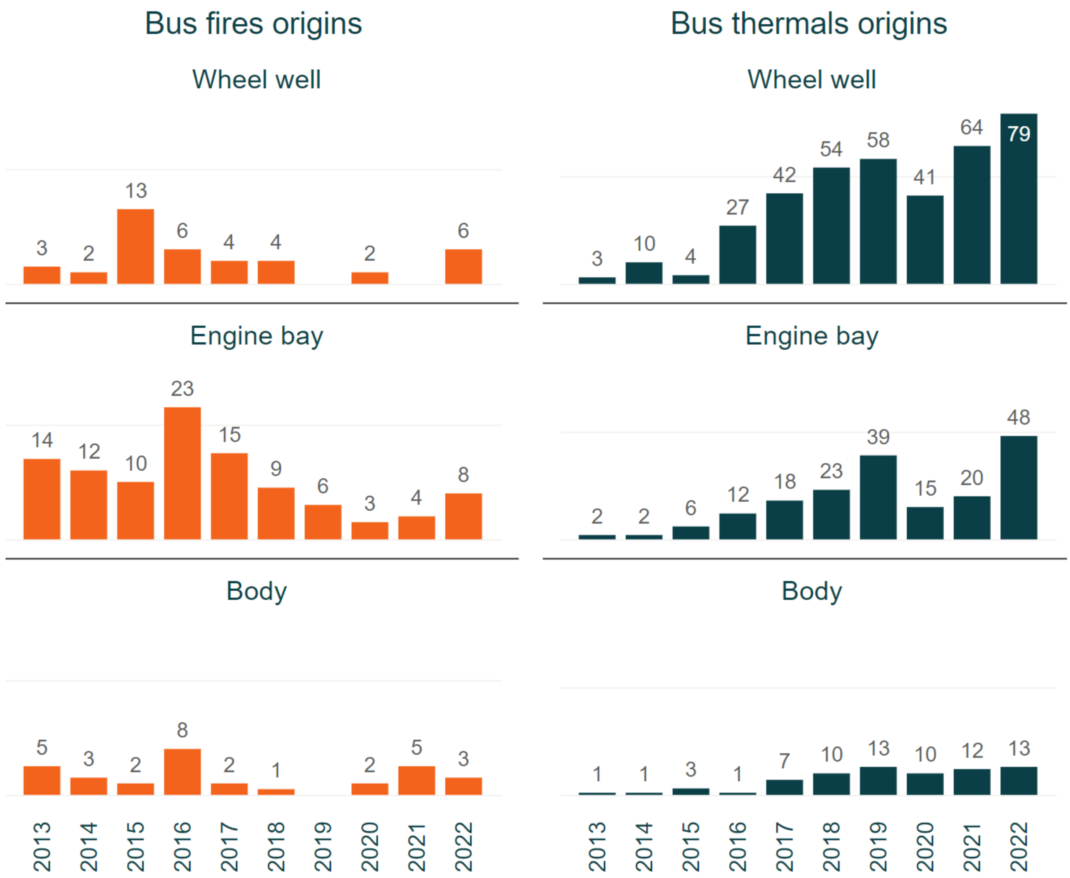

Figure 15: The year-by-year distribution of which area of the bus did the fires and thermals originated from over the last decade.

To explore if a systemic change (e.g. a change in the electrical system) is potentially causing more fires or thermals to originate from a particular area, the origins data was normalised with respect to the total number of fires (for fire origins) or thermals (for thermal origins) in a given year. Figure 16 displays the normalised graphs which confirmed that **although thermal incidents have been increasing over the years, the relative percentage contributions of the incidents originating in the wheel well, engine bay and body of the bus have largely stayed the same**. This was confirmed through statistical analysis as well, with the absolute values of the statistical correlation coefficients for all trends for the bus thermals in Figure 16 being less than 0.16, indicating a very weak correlation. This suggests that **systemic changes or fire safety interventions have likely had minimal effect on bus thermal incidents and their origins in the last decade**.

Considering the low number of fires, no statistical analyses were performed on the normalised trends for fire origins. However, data indicated **a reduction in the percentage of bus fires originating in the engine bay** in the 2020-2022 period compared to the 2013-2019 period, which is **likely a consequence of the installation of fire suppression systems in the engine bays** of the TfNSW contracted buses. Nevertheless, **engine bay remains the most dominant area of origin for fires**, which can partly be attributed to the **lack of mandate on the installation of engine bay fire suppression systems in all buses.** This includes coaches which have no EBFSS and only one door for entry and exit, thus posing a potential threat to passenger safety in case of a fire.

The continued dominance of the engine bay as the area of origin for bus fires also suggests the **need to review the effectiveness of existing fire suppression technologies and to explore further technological solutions**. Further analysis of the causes of engine bay originated fires is done in the following section.

Further, although more data is required for confirmation, Figure 16 also shows an increase in the percentage of bus fires originating in the body of the bus in the last three years. Considering that automatic fire suppression technologies are currently not fitted in the body of most buses, this finding implies a risk to passenger safety. It also highlights the need to investigate the flammability of materials used in the body of the bus and the introduction of associated fire-retardant standards.

Collectively, the above findings highlight the need to **1) review Australian Design Rules for the inclusion of fire suppression systems in all buses (including coaches), 2) investigate the flammability of the materials used in the body of the bus, 3) review the efficiency of existing fire safety interventions, and 4) explore other fire suppression technologies available for the engine bay, body and wheel well of the buses.**

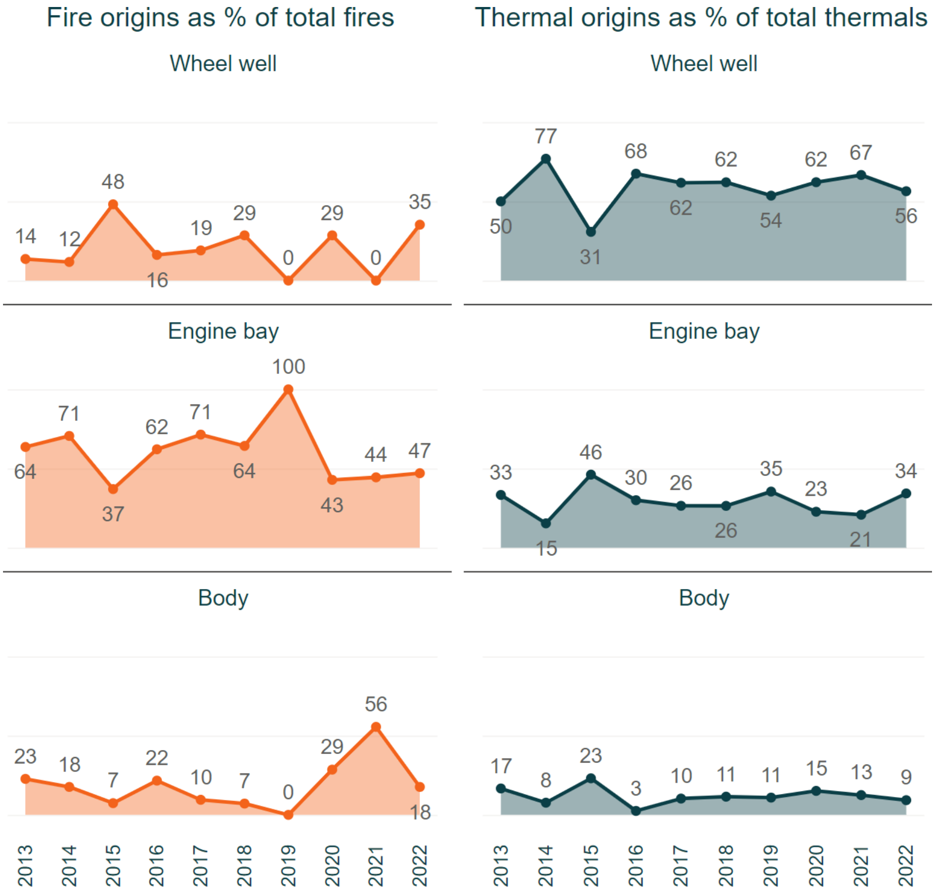

Figure 16: The normalised year-by-year distribution of the bus fires and thermals origins presented as a percentage of the total fires and thermal incidents in the respective year, respectively.

Causes

OTSI's classifications of the causes include brakes, electrical, fluid, mechanical, tyres and other (which includes arson).[14] Since the number of incidents with causes of "tyres", "other" and "unknown" were small over the last decade, they were combined into the "other" category.

As per Figure 17**, the most common cause of bus fires in the last decade was electrical faults,** followed by fluid leaks, brakes and other mechanical issues. **For thermal incidents, the most**

[14] In the 2021 Bus Fire Safety Report, all incidents with cause type "brake" were classified as "mechanical". However, based on internal consultation, the categories listed in this report have been decided for the classification of the causes of the bus fire and thermal incidents. All previous data has been cleansed and reclassified accordingly.

common cause in the last 10 years was brake problems. This aligns with the observation above that most fires originate in the engine bay area and most thermal incidents originate in the wheel well area (see Figure 14).

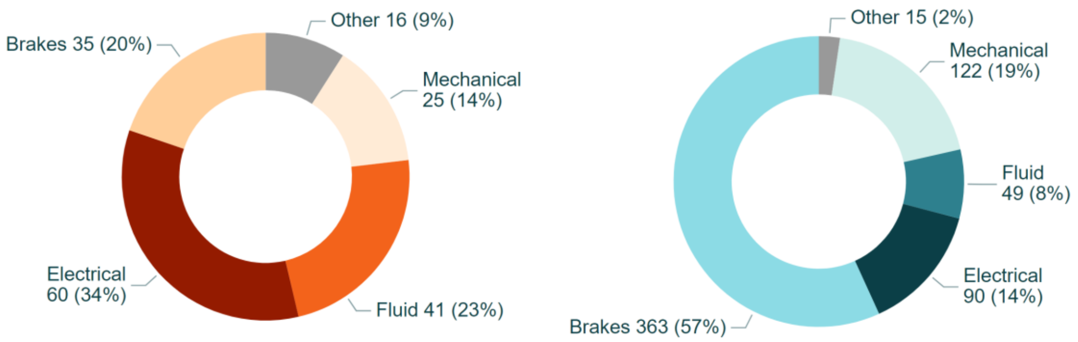

Figure 17: The distribution of the causes, as per OTSI's classification, for the bus fire and thermal incidents in NSW in the last 10 years.

Figure 18: The year-by-year distribution of the different causes of the bus fire and thermal incidents in NSW over the last decade. Note that, ~9% of the fire and 2% of thermal incidents had "other", "tyre" or "unknown" reasons and have not been shown in this figure.

The year-by-year trends of the causes of bus fire and thermal incidents in NSW over the last decade are shown in Figure 18. Of interest is the dramatic increase (680%) in the number of bus thermal incidents due to mechanical problems in 2022 over 2021. As discussed in the previous section, 92% of the mechanical problems observed in 2022 led to thermal incidents originating in the engine bay.

The normalised trends for the causes of bus fire and thermal incidents are shown in Figure 19. No major change in the percentage of bus fires caused by brakes, electrical, fluid or mechanical problems was observed over the last decade. For bus thermal incidents, a regular decline in the percentage of incidents caused by fluid leaks over the last 10 years was observed (the statistical correlation coefficient was found to be -0.82, confirming strong negative correlation).

The above findings suggest that **bus fire safety intervention or changes to bus designs have likely had limited effect on preventing the initiation of bus fires in the last decade.** However, **some change or safety intervention has resulted in continuous reduction of bus thermals caused due to fluid leaks.** Further investigation into this reduction may assist in the identification of potential contributing factors and/or development of further interventions.

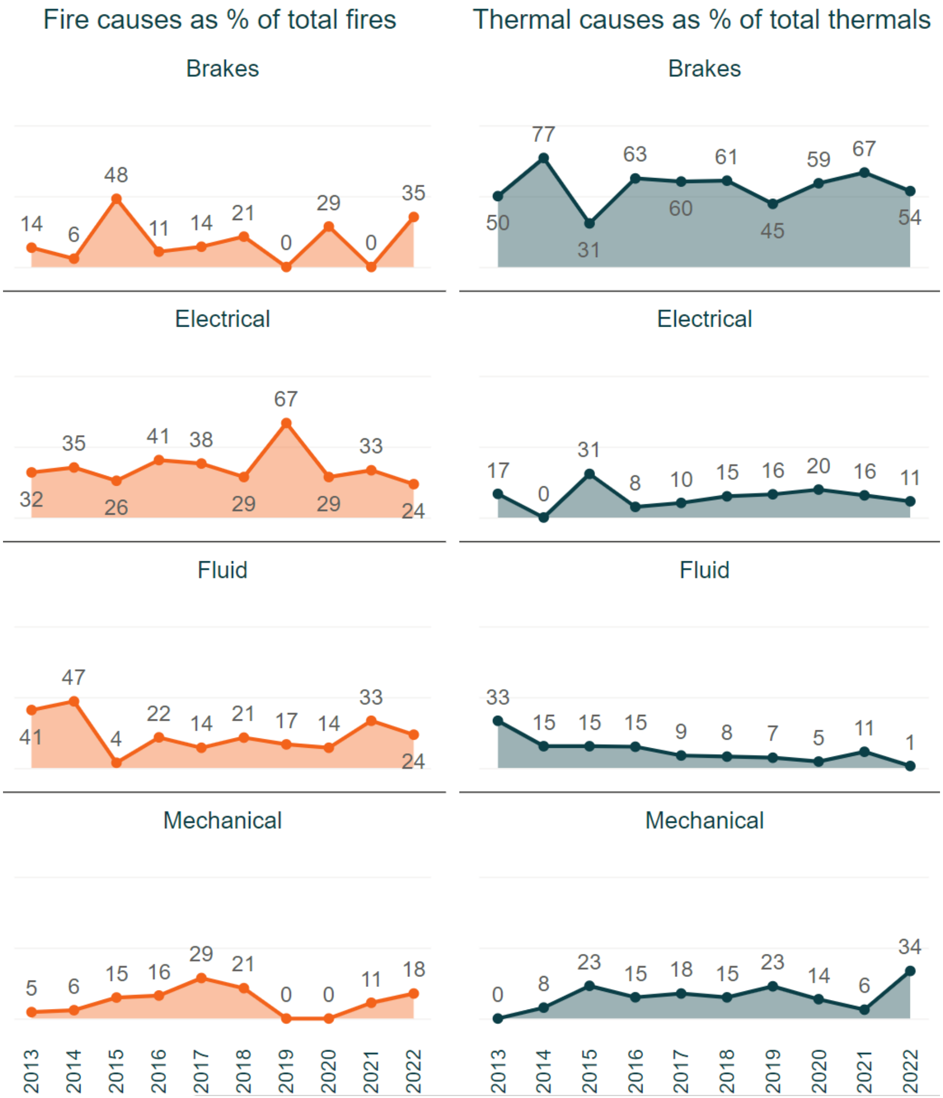

Figure 19: The normalised year-by-year distribution detailing the cause of the bus fires and thermal incidents, presented as a percentage of the total fires and thermal incidents in that particular year, respectively. Note that, ~9% of the fire and 2% of thermal incidents had "other", "tyre" or "unknown" reasons, which have not been shown in this figure.

In line with previous years' reports, OTSI also investigated the breakdown of causes of fires originating from the body, wheel well and engine bay, separately. As per Figure 20, **most fires and thermals originating in the body of the bus in the last decade were caused by electrical faults.** Similarly, **most wheel well originated fires and thermals in the last decade were caused due to problems with the brakes.** For fire and thermal incidents that originated in the engine bay, the distribution of causes was much more diverse and varied greatly.

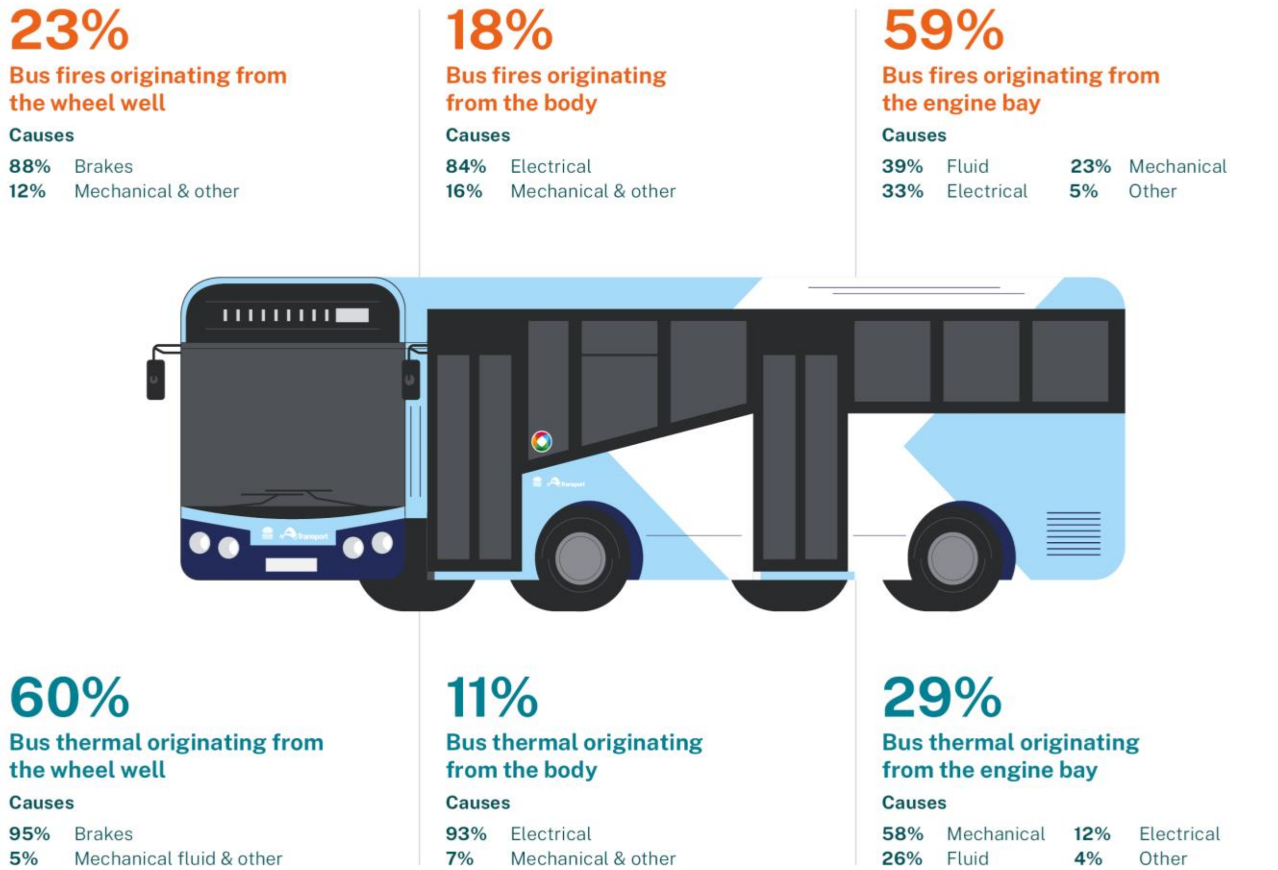

Figure 20: A summary of causes of bus fire and thermal incidents originating in the engine bay, wheel well, and body of the buses in the last 10 years.

The above findings present opportunities for the development and/or implementation of targeted fire safety solutions in buses. For example, with electrical faults being the leading cause of bus fires in the last decade, a review of the configuration management, maintenance, and inspection of different electrical components in buses (such as wiring, circuitry, and batteries) may assist in the reduction of bus fires. OTSI has issued three Safety Advisories and one Safety Alert on these issues.[15,16,17,18]

[15] Safety Advisory SA01/23, Office of Transport Safety Investigations, 2023, I02028, https://www.otsi.nsw.gov.au/publications/safety-alerts-and-safety-advisories/bus-safety-alerts-and-safety-advisories/safety-advisory-sa0123-protection-electrical-circuits-buses

[16] Safety Advisory, Office of Transport Safety Investigations, 2021, I02009, https://www.otsi.nsw.gov.au/documents/safety-advisory-i02009-risk-air-conditioning-system-electrical-fires-buses-5-november-2021

[17] Safety Advisory SA03/23, Office of Transport Safety Investigations, 2023, N27536, https://www.otsi.nsw.gov.au/publications/safety-alerts-and-safety-advisories/bus-safety-alerts-and-safety-advisories/safety-advisory-sa0323-securing-bus-batteries-cabling-and-protective-covers

[18] Safety Alert, Office of Transport Safety Investigations, 2021, https://www.otsi.nsw.gov.au/documents-archived/safety-advisory-bus-safety-alert-risks-electrical-fires-volvo-buses-volgren-cr228l-bodies-20-january-2021

Potential contributing factors

In this section, bus age, bus year of manufacture and weather conditions have been explored as potential contributing factors to bus fire and thermal incidents. These factors and analyses have been selected to clarify some common misconceptions, and to answer the following questions that are frequently asked in the industry:

- Are buses more likely to have a fire or thermal incident in hot weather conditions?
- Are older buses more likely to have a fire or thermal incident?
- Are older buses more likely to sustain more severe damage if involved in a fire-related incident?
- Is a particular batch of buses (i.e., buses manufactured in a particular year) more likely to have a fire or thermal incident?

Several additional factors such as fuel type, bus load, road congestion, and bus maintenance and servicing schedules, should be explored as potential contributing factors to bus fire and thermal incidents. However, such diagnostic analyses require the availability of baseline data to normalise the incident data captured by OTSI. Such baseline data was either not available for these factors or could not be obtained in time for analysis for this report.

OTSI notes that the establishment of a national database to record all bus fire and thermal incidents, and to provide consistent bus fleet data for all states and territories would significantly assist the identification of additional potential contributing factors and will improve statistical relevance of the diagnostic analyses in this section. The need for a national database was also highlighted by the Bus Industry Confederation's fire mitigation advisory published in 2014,[19] and OTSI's bus fire safety report published in 2012.[20]

Age of buses

Since the first bus fire safety report by OTSI in 2013, the age of buses has been hypothesised as a potential contributing factor to bus fire and thermal incidents. Most of the annual bus fire reports published by OTSI since 2013 have included some correlational analysis of bus age and the number of fire and thermal incidents, with varying findings over the years. In this report, OTSI analysed the data collected over the last decade to obtain a definitive answer about whether the age of buses is a contributing factor to fire and thermal incidents, and/or the level of damage a bus sustains.

To begin with, OTSI compared the average age of the NSW bus fleet[21] with the average age of the buses that have caught fire or have been involved in thermal incidents in the last decade. As shown in Figure 21, the decadal average age of the buses involved in fires (12.0 years) or thermal incidents (11.7 years) is higher than the decadal average age of the NSW bus fleet (11.3 years). A significant shift in the trend of the average age of the buses involved in thermals was observed in 2018. **Before**

[19] Fire mitigation advisory, Bus Industry Confederation, 2014, https://movingpeople.com.au/wp-content/uploads/doc/GA005.pdf

[20] Bus safety investigation report, Office of Transport Safety Investigations, 2012, 04601, www.otsi.nsw.gov.au/sites/default/files/2022-06/bus_safety_investigation_report_bus_fires_nsw_2005_to_2012.pdf

[21] Unlike Figure 2b, the annual average ages of the NSW bus fleet presented in this section and Figure 21 (left) are calculated based on the December snapshots (for years 2013-2022, and June snapshot for 2022) of the NSW registrations data of heavy vehicle buses. This was done to allow meaningful comparisons between the average ages of the NSW bus fleet, and the buses that have been involved in a fire or thermal incident. See footnote 3 for more details.

2018, the annual average age of the buses that had a thermal incident was 7-10 years old. In 2018, this number rose to ~12 years and has stayed ≥12 years since then. In fact, the annual average age of buses involved in thermals has been continually increasing since 2016. This analysis suggests that 1) buses manufactured in certain years may be more prone to thermal incidents, or 2) some systemic change took place in or around 2018, which led to more older buses getting caught in thermal incidents. OTSI has investigated the first possibility in the next section and is considering the second possibility for further investigation.

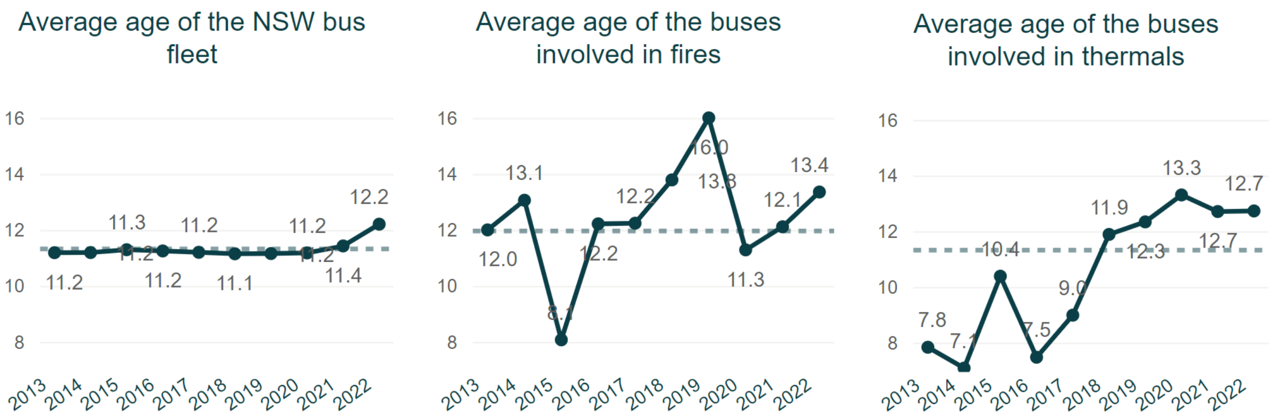

Figure 21: The average age (in years) of the NSW bus fleet[21] (left), buses involved in fires (middle), and buses involved in thermals (right). The dotted line indicates the decadal average age of 11.3 years for the bus fleet, 12.0 years for the buses involved in fires, and 11.7 years for buses involved in thermals.

OTSI also analysed the age distribution of all buses that have had fire or thermal incidents in the last 10 years. As shown in Figure 22, the majority of thermal incidents in the last 10 years occurred in buses that were 8-10 years old. For fires, two clusters were observed, with the majority of fires occurring in buses that were 5-9 years old and 12-16 years old. Additionally, very few fire and thermal incidents occurred in young (<4 years old) or very old (>25 years old) buses. However, this could be because there were fewer buses of those ages in the NSW bus fleet. To address this issue and to allow for meaningful comparisons, the age distribution data for bus fire and thermal incidents (i.e., Figure 22) was normalised to the age distribution of the NSW bus fleet (i.e., the sum of data across 2013-2022 from Figure 3), as shown in Figure 23.

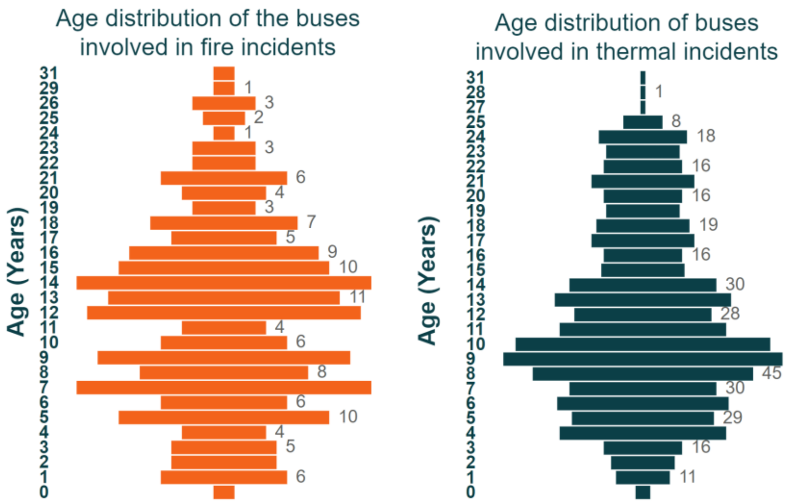

Figure 22: The age distribution of the buses involved in fire and thermal incidents from 2013-2022. The largest horizontal orange bar (fires) represents 14 buses, and the largest horizontal teal bar (thermals) represents 57 buses.

The normalised age distribution of the buses involved in fire and thermal incidents (Figure 23) shows that **12-16 years old buses are most likely to have a fire incident whereas 8-10 years old buses are most likely to have a thermal incident**. This difference in the ages of the buses involved in fires and thermals aligns with the average age analysis (Figure 21).

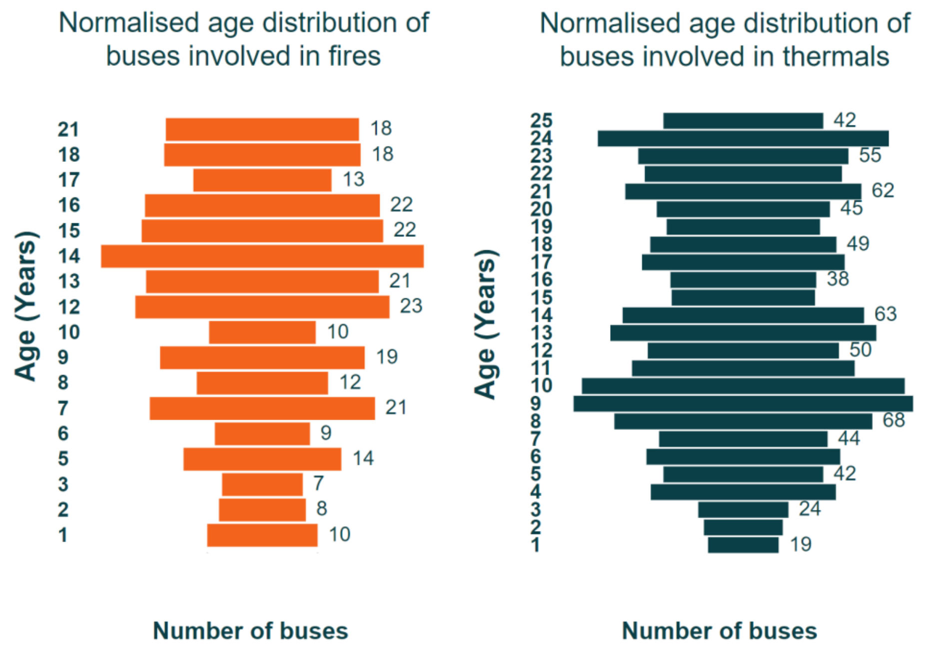

Figure 23: The normalised age distribution of the buses involved in the fire and thermal incidents based on the data from 2013-2022. As an example of how to read these graphs, annually, out of every 10,000 five-year old buses, 14 (i.e. 0.14%) have caught fire and 42 (0.42%) have been involved in thermal incidents. Note that for statistical relevance, only those age groups are shown which have had at least 5 incidents in the last decade.

Are older buses more likely to have a fire or thermal incident?

To deduce if the likelihood of a fire or a thermal incident increases with the age of the bus, statistical analyses were performed on the normalised age distribution data of the incidents. Correlational analysis of the decadal data with a minimum of 5 incidents per age group (i.e., Figure 23) showed that overall, there is a moderate positive correlation (correlation coefficient = 0.59) between the likelihood of a bus fire incident and the bus age, and weak correlation (correlation coefficient = 0.29) between the likelihood of a bus thermal incident and the bus age.

When repeating the above analyses for age subgroups, a strong correlation was found between the likelihood of a bus fire and the bus age for 1-16 years old buses (correlation coefficient = 0.8). For buses aged >16 years, the correlation coefficient was found to be -0.11, indicating very weak negative correlation.

Interestingly, the correlation between the likelihood of a thermal incident and the bus age was found to be very strong for buses aged 0-10 years old (correlation coefficient = 0.94), strongly negative (-0.69) for buses aged 10-20 years old, and weakly positive (0.13) for buses aged >20 years.

The above findings can be interpreted as follows. Based on the statistical analyses of the data from the last 10-years, **bus age is identified as a potential contributing factor to bus fire and thermal incidents. The likelihood of a bus fire or thermal incident increases with bus age until the buses are ~14-16 years old (for fires) and ~10 years old (for thermals)**. After this age, bus fire incidence rate stays about the same, whereas bus thermal incidence likely decreases with bus age. Note that this data analysis is based on small numbers (especially for fires). A larger dataset (e.g. by considering national data) would allow for a more conclusive analysis to be undertaken.

Nevertheless, the identified correlation between bus age and bus fire and thermal incidence rates suggests that **a review of the average age and age distribution of the NSW bus fleet may help reduce bus fire and thermal incidence rates**. The bus fleet analysis (Figure 2) has shown that the average age of the NSW bus fleet has been increasing in the last few years, reaching a peak in 2022. Further, bus fleet age distribution analysis (Figure 3) has shown that new bus deliveries have varied significantly over the years. A major delivery of new buses in a year was followed by much fewer new bus deliveries in the subsequent years. This has resulted in big clusters of buses of a particular age group. As these clusters age, the likelihood of the bus fire and thermal incident increases. Therefore, **it may be beneficial to review the purchasing patterns and adopt a more consistent approach to maintain a regular delivery of new buses.**

Are older buses more likely to sustain more severe damage if involved in a fire-related incident?

To deduce the likelihood of an older bus sustaining more severe damage due to a bus fire or thermal incident, OTSI first determined the average age of buses categorised by the levels of damage over the last decade. As shown in Figure 24, the decadal average age of buses that sustained major (or more severe) damage was found to be higher than that of buses sustaining minor or lower damage. However, this can be partly attributed to the fact that destroyed or major damage was mostly caused by fires, whereas minor or no damage largely resulted from thermal incidents (see Figure 9), and considering that the average age of the buses involved in fires was higher than that of the buses involved in thermal incidents (see Figure 21).

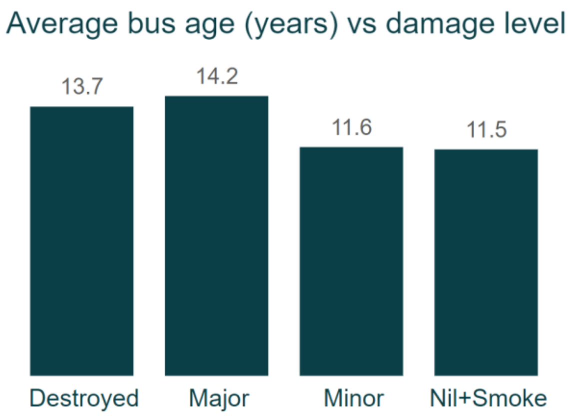

Figure 24: The average age of the buses categorised by the level of damage they sustained due to a fire or thermal incident, based on the data obtained by OTSI from 2013-2022.

Nevertheless, the average age of destroyed (13.7 years) or majorly damaged (14.2 years) buses was found to be significantly higher than the average age of the buses involved in fires (12.0 years as per Figure 21). This suggests the possibility of some correlation between bus age and severity of damage.

To further explore this correlation, the age distribution of destroyed or majorly damaged buses (due to fires) was normalised to the age distribution of the total number of buses involved in fires (i.e., Figure 22). The correlation analyses of this normalised data, shown in Figure 25, confirmed a moderate positive correlation (correlation coefficient = 0.59) between bus age and the likelihood of bus sustaining major or more severe damage. However, with the low number of bus fires (especially for buses of certain ages), such analysis can present uncertainty. Considering this, and based on the results presented in this section, OTSI concludes that **although there is some evidence to suggest that for buses involved in a fire, the likelihood of a bus sustaining major or more severe damage increases with bus age, more data is required to confirm the relationship.**

If the above correlation is confirmed, it will provide further support to the recommendation from the previous section that **a review of the average age and age distribution of the NSW bus fleet may help reduce bus fire and thermal incidence rates.**

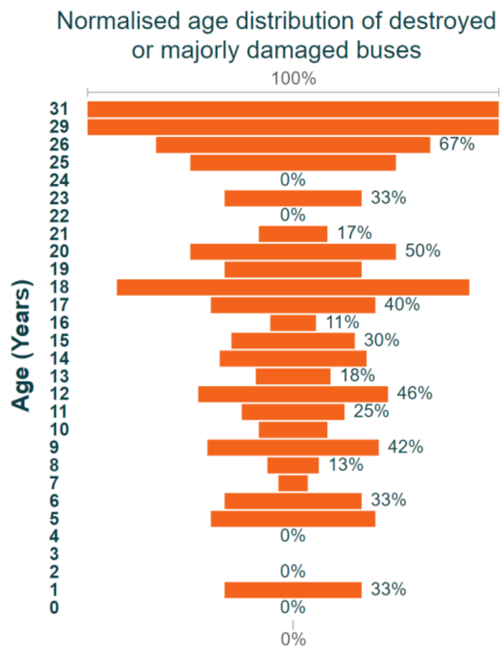

Figure 25: The age distribution of the destroyed or majorly damaged buses in the last decade, normalised to the age distribution of the total number of buses involved in a fire. As an example, this graph shows that 42% of the 9-year-old buses, and 86% of the 18-year-old buses that were involved in a fire in the last decade sustained major damage or were destroyed.

Year of manufacture

Is a particular batch of buses (i.e. buses manufactured in a particular year) more likely to have a fire or thermal incident?

The age of bus analyses described in the previous sections highlighted the possibility that buses manufactured in certain years may be more prone to fire or thermal incidents. To test this hypothesis and to explore bus year of manufacture as a potential contributing factor, in this section, OTSI analysed the total number of incidents in the last decade against the year of manufacture of the buses involved in the incidents, as shown in Figure 26.

The analysis showed that buses manufactured in 2009 had the largest number of fire and thermal incidents in the last decade. As before, for accurate comparison, the absolute number of fire and thermal incidents for a particular year of manufacture were normalised to the total number of buses manufactured in that year. The analysis, shown in Figure 27, revealed that by considering data points with at least 5 incidents, **buses manufactured in 2004 had the highest annual incidence rate of bus fires, and buses manufactured from 2009-2011 had the highest thermal incidence rate.** This confirms that **bus year of manufacture is a potential contributing factor to bus fire and thermal incidents.** That is, certain batches of buses do have a higher likelihood of being involved in a bus fire or thermal incident. Considering that as of June 2022, the NSW bus fleet had 2,357 registered buses that were manufactured in 2009-2011, and 269 registered buses manufactured in 2004, further investigation into these buses may reveal factors leading to their higher fire or thermal incidence rates compared to other buses, which may in turn assist in the development of fire safety solutions.

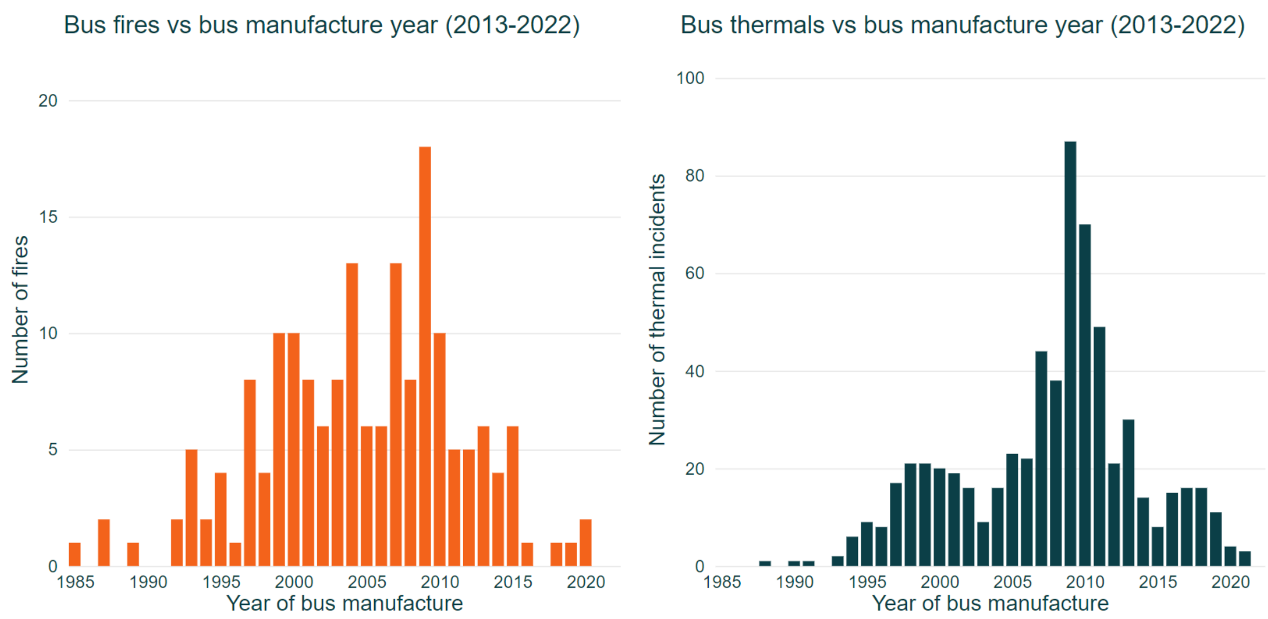

Figure 26: The overall distribution of the total number of bus fire and thermal incidents from 2013-2022, based on the year of the manufacture of the buses involved in the incident.

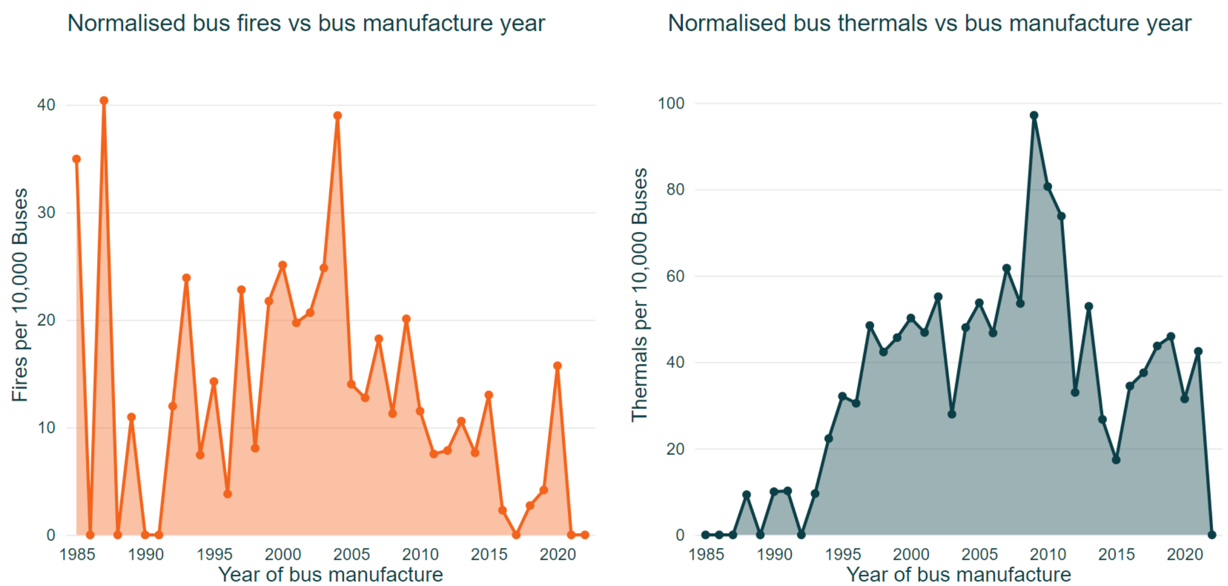

Figure 27: Normalised distribution of the buses involved in the fire or thermal incidents, based on their year of manufacture. As an example, these graphs indicate that on average, annually, out of every 10,000 buses that were manufactured in 2009, 20 (i.e., 0.20%) had a fire, and 97 (i.e. 0.97%) had a thermal incident in the last decade.

Time of day

To explore weather conditions as a potential contributing factor to bus fire and thermal incidents, OTSI analysed two categories: incident time, and incident month, as discussed below.

To determine if bus fire and thermal incidence rate is higher at particular times of the day, OTSI categorised the total number of bus fire and thermal incidents from 2013-2022 by the time at which the incident occurred, rounded to the nearest hour. This hourly distribution, displayed in Figure 28, shows that most bus fire and thermal incidents in the last decade occurred in the morning and afternoon rush/peak hours (7-10 am and 3-6 pm). To draw any conclusions about the effect of congestion or outside temperature on the likelihood of a fire-related incident, this data should ideally be normalised to the number of bus services operating per hour throughout NSW. However, OTSI was unable to obtain this data. Therefore, the baseline data from the hourly distribution of the Opal bus trips was used for normalisation.[22]

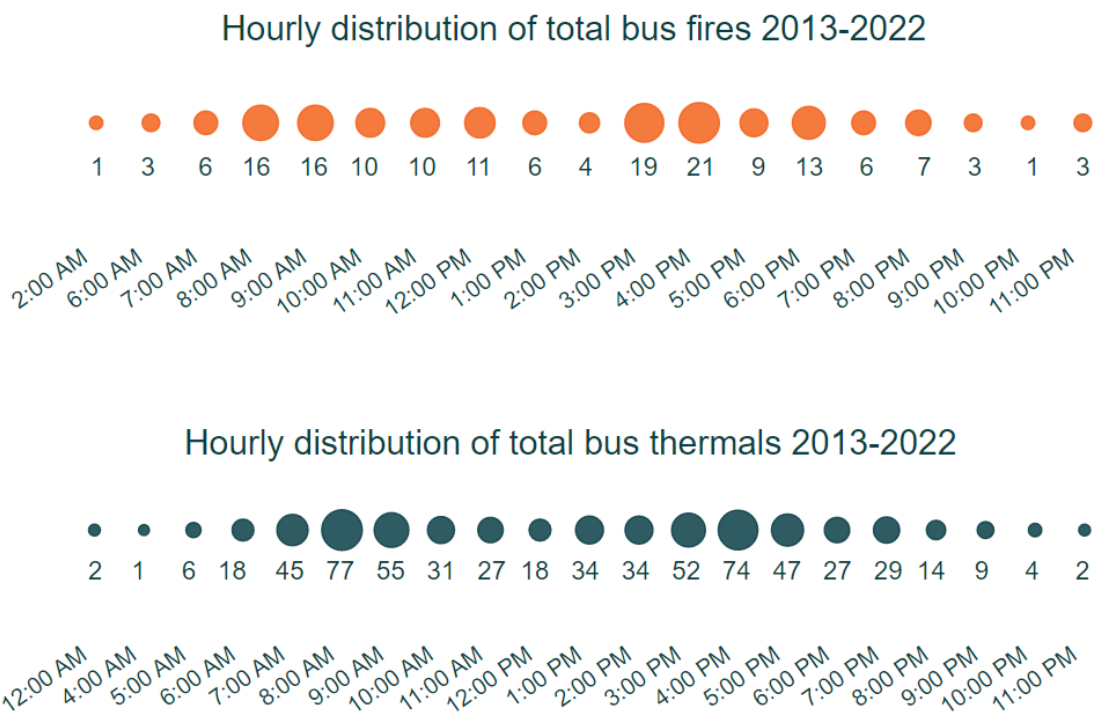

Figure 28: Hourly distribution of the total number of bus fire and thermal incidents in NSW from 2013-2022.

The hourly distribution of the incidence data normalised to Opal bus trips is shown in Figure 29. Note that only those data points are shown where there were at least five incidents over the last decade. The normalised data reveals that even after factoring in more frequent bus trips during the peak rush hours, the incidence rates of bus fires and thermals, relative to the Opal trips, was found to be higher during the morning and afternoon peaks than the typically hotter hours of the day. The highest incidence of bus thermals was found to be from 7:30 – 9:30 am, 3.30 – 4:30 pm and 6:30 –

[22] Sample hourly opal data (opal bus trips) was captured from https://www.transport.nsw.gov.au/data-and-research/data-and-insights/interactive-data-visualisation-tool for a few weekdays and weekends, both during school holidays and school days. This data was then used to estimate hourly distribution of the total number of opal bus trips in a year, by counting the total number of weekends, weekdays during school holidays and weekdays during normal school days. This estimation was only performed for 2022, but it was assumed that the general trends would be similar for other years. Therefore, this estimated data has been used for the normalisation for the time-of-day analysis. OTSI was unable to obtain the actual hourly data on the opal bus trips in time for analysis for this report.

7:30 pm. The bus fire incidence rates showed similar trends. However, bus fires were found to have similar incidence rates at 9 am and 8 pm.

The time-of-day analyses suggest that hotter weather conditions are likely not a potential contributing factor, whereas road congestion and/or a higher bus load may be. These findings are potentially contradictory considering outside weather conditions, road congestion and bus load can all increase operating temperatures through increased pressure on the mechanical and electrical areas of the bus. Therefore, it is important to verify these correlations through further data and analyses. If confirmed, then mechanical basis behind these correlations should be investigated to identify the root causes. For example, road congestion can increase pressure on the engine and/or brakes due to the start-stop pattern of driving, which may be further exacerbated by a higher bus load. Similarly, hot weather conditions and air conditioning can increase the operating temperatures of the engine. An investigation into these issues may help develop fire safety solutions, for example, through increased maintenance and/or inspection schedules.

Weather conditions are further explored as a potential contributing factor using the incident month analysis in the next section. However, baseline data could not be obtained to further investigate bus load and road congestion as potential contributing factors in this report. They will be considered for further investigation and inclusion in later reports.

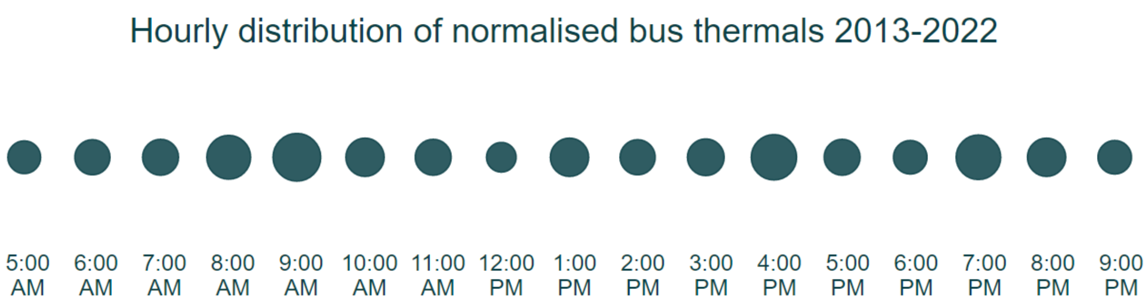

Figure 29: Hourly distribution of the total number of bus fire and thermal incidents, normalised to the estimated Opal bus trips. Note that data for only those hours is shown, where there were at least 5 incidents in the last decade.

Month

The observed monthly variance in bus fire and thermal incidents based on the data from 2013-2022 is shown in Figure 30.

The analysis shows that most fires occurred in October, followed by January and March, and most thermals occurred in August, followed by September. In the absence of data on the monthly distribution of total active bus services, OTSI used average monthly Opal bus trips based on data from July 2016 – Dec 2022[23] for normalisation.

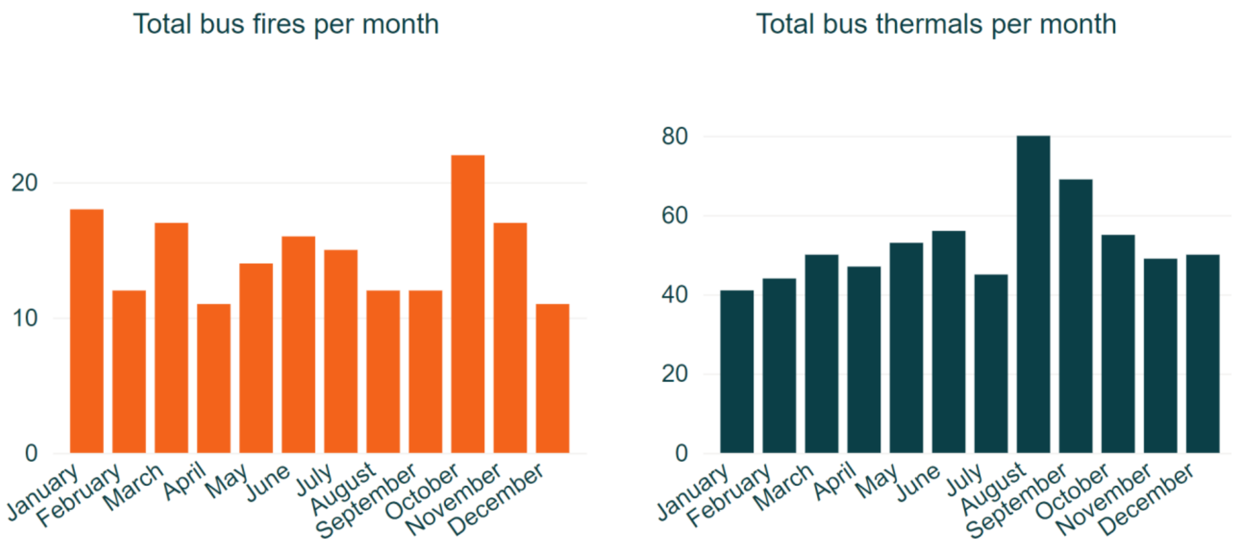

Figure 30: Monthly distribution of the total number of bus fire and thermal incidents recorded in NSW from 2013-2022.

The normalised data, displayed in Figure 31, shows that in the last decade, **October and January had the highest bus fire incidence rates, and August and September the highest bus thermal incidence rates.** This analysis highlights that 1) monthly incidence trends for bus fire and thermal incidents are very different, and 2) there may be a negative correlation between thermal incidents and hot weather, with highest thermal incidence rates observed in late winter and early spring over the last decade. This potential correlation is further explored in the next section.

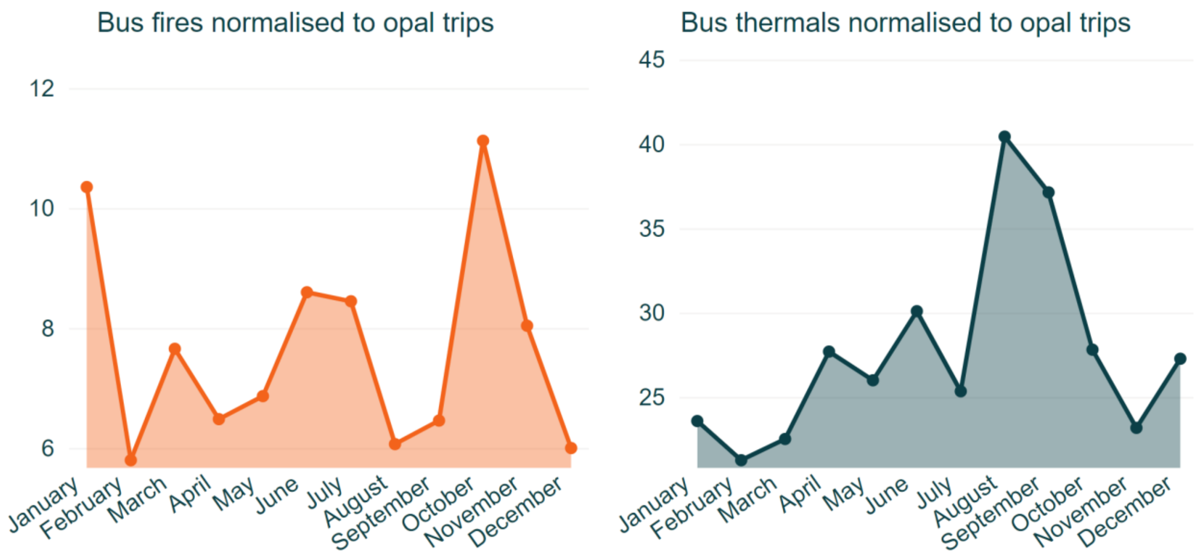

Figure 31: Monthly distribution of the bus fire and thermal incidents in NSW from 2013-2022, normalised to the average monthly Opal bus trips. The y-axis represents the number of incidents per 1M Opal bus trips in that month.

[23] Based on the snapshot acquired from https://opendata.transport.nsw.gov.au/dataset/opal-trips-bus on 08 March 2023.

Are buses more likely to have a fire or thermal incident in hotter weather conditions?

The normalised time-of-day analysis (Figure 29) shows that bus fire and thermal incidence rates over the last decade were lower during the typically hotter hours of the day compared to morning or late afternoon. Similarly, the normalised monthly analysis (Figure 31) showed lower (or equal) incidence rates in the typically hotter months of the year compared to the colder months. Both these observations are inconsistent with the general opinion that the likelihood of a bus fire or a thermal incident increases in hotter weather conditions.

To obtain some statistical significance, OTSI further explored the correlation between the fire/thermal incidence and outside temperature (weather). First, the mean maximum temperature of NSW was calculated for every month using at least 28 years of meteorological data.[24] Correlation analysis was then performed between the mean monthly maximum temperature and the normalised monthly incidence rates (Figure 31). Results showed no (or very weak) correlation (correlation coefficient = 0.03) for bus fires, and moderate negative correlation (-0.57) for bus thermals. This suggests that **the bus fire incidence rate in the last decade has been largely independent of the outside temperature (weather)**, and the **bus thermal incidence rate has likely been higher in colder weather.**

The above analyses collectively indicate that **there is no evidence to suggest that buses are likely to have higher fire or thermal incidence in hotter weather conditions.** As discussed earlier, this finding potentially contradicts the initial indications from the incident time analysis (see 'Time of day') that bus load and/or road congestion may have a positive correlation with bus fire and thermal incidence rates. Therefore, mechanical basis of these potential correlations should be investigated to develop fire safety solutions for buses.

[24]Monthly mean maximum temperature = average of the maximum daily temperatures. Monthly mean maximum temperature for NSW was calculated by averaging multiple years of data obtained from the following weather stations: Sydney Airport AMO (1939-2023), Parramatta North (1967-2023), Penrith Lakes AWS (1995-2023), Tamworth Airport AWS (1992-2023) and Newcastle Nobbys (1862-2023). These stations were selected based on the location and incidence rates of the bus fire and thermal incidents in the last 10 years. All meteorological data was sourced from the Bureau of Meteorology (http://www.bom.gov.au/climate/data/index.shtml).

Fire safety interventions

Several fire safety initiatives and interventions have been introduced and implemented over the past decade to improve bus fire safety in NSW. These include:

- installation of third-party fire suppression and/or detection systems such as EBFSS and tyre monitoring systems (TMS)
- changes to operators' policies, standards, and safety management systems
- review of bus design, and inspection and maintenance schedules
- improvement in driver training
- increased awareness of the risk and dangers of bus fires and their common causes
- other technological advancements.

This section presents the estimates of economic savings that the above bus fire safety initiatives and interventions have delivered to NSW over the last decade, and the projections of savings they are expected to deliver in the next decade, as determined by HoustonKemp. The effectiveness of the existing fire safety technologies including EBFSS, TMS and portable fire extinguishers has also been reviewed to highlight next steps in bus fire safety improvement for NSW.

Economic impact

It is estimated that **more than $15.5 million in bus fire costs have been avoided in NSW between 2013 and 2022** in present value terms (expressed in 2022 dollars) compared to a hypothetical counterfactual where no safety interventions or initiatives occurred. This translates to an annual savings of $2.0 million in avoided costs. This result arises due to a decrease in the incidence of bus fires compared to the anticipated case based on the rate of bus fires[25] that occurred between 2013 and 2015. The estimation process and the modelling details are given in 'Appendix C – Approach to the assessment of economic costs and benefits'.

As shown in Figure 32, the avoided cost of bus fires that have been achieved since 2013 can be viewed in three main categories, namely:

- avoided indirect travel delay costs ($9.9 million)
- avoided risk of injury or potential for a fatality ($3.2 million)
- avoided congestion arising from a lower number of bus fires ($3.1 million).

Other avoided costs evaluated included avoided emergency service costs and reduced direct travel delay costs however these categories made up a negligible proportion of total avoided costs (two and one per cent of total avoided costs respectively).

The avoided cost of bus replacement or repair was found to be negative as part of this evaluation, i.e., the estimated cost of bus replacement and repair for observed bus fire incidents was higher than the average rate of bus fires from 2013 to 2015. In large part, this result is driven by an increase in observed bus fire incidences in 2016, and the observed degree of bus fire damage being more severe than implicitly assumed in the hypothetical counterfactual.

[25] Incidence of bus fires is based on the observed rate of bus fires per scheduled service kilometre.

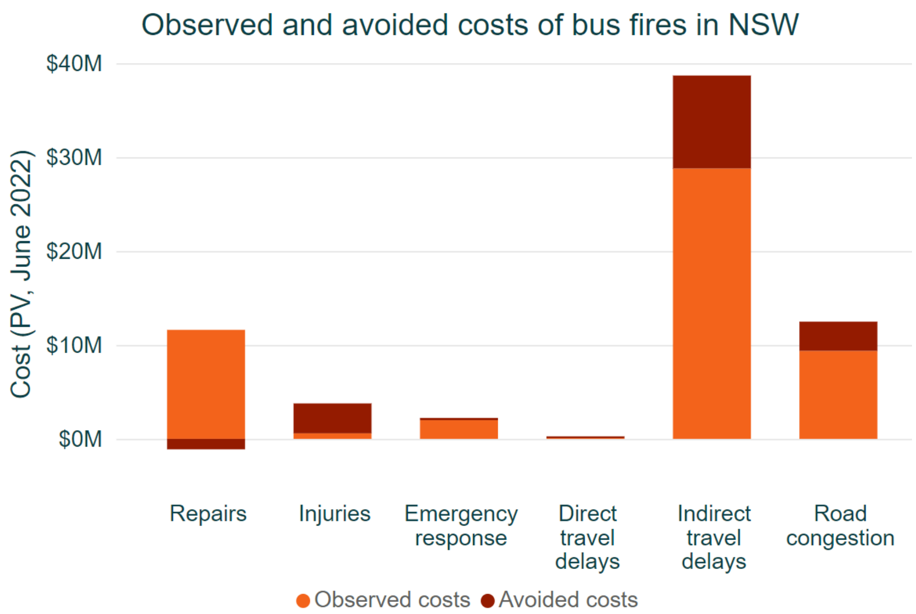

Figure 32: Estimates of the observed and avoided costs of the bus fires in NSW between 2013 and 2022.

It is projected that the **existing fire safety interventions will continue to deliver approximately $19.0 million in present value terms in benefits ($2.5 million per year) to NSW over the next ten years.** This benefit arises from an enduring reduction in the rate of bus fires achieved from 2013 to 2015 levels. See 'Appendix C – Approach to the assessment of economic costs and benefits' for more details on the modelling and estimation process.

Effectiveness of the current interventions

Although existing fire safety interventions have delivered, and are expected to continue delivering, economic savings to NSW through avoided incidents and reduced severity, significant increase in bus fire and thermal incidence rates in recent years (see 'Bus fire and thermal incidents' section), and the projected increase in the incidence rates and their costs to NSW over the next decade (see 'Projected costs' in the 'Measuring the impact' section), necessitated a review of the efficacy of the existing interventions. This section reviews the effectiveness and use of portable fire extinguishers, engine bay fire suppression systems and tyre monitoring systems.

Portable fire extinguishers

As part of the Australian Design Rule 58/00, all buses are required to be equipped with a readily accessible fire extinguisher.[26] Previous annual bus fire safety reports and incident investigation reports published by OTSI since 2013 have highlighted issues with the location of the fire extinguisher in the bus, and a lack of driver training on the use of fire extinguishers. In this report, OTSI analysed the data collected from 2013-2022 to determine trends in the use of fire extinguishers and its success in eliminating flames.

As shown in Figure 33, the percentage of bus fire and thermal incidents where a portable fire extinguisher was used has been largely decreasing over the years. This was verified statistically as

[26] https://www.infrastructure.gov.au/infrastructure-transport-vehicles/vehicles/vehicle-design-regulation/australian-design-rules/third-edition

well – the correlation coefficients for the trends of the percentage of incidents where fire extinguisher was used in Figure 33 was found to be -0.62 (for bus fires) and -0.94 (for bus thermals). This indicates strong and very strong negative correlations, respectively (as per footnote 12).

In the case of bus thermal incidents, with no visible flames, the use of a fire extinguisher is likely precautionary, with further analysis unlikely to provide useful insights. However, for bus fires, a continuous reduction in the percentage of incidents where the portable extinguisher was used suggests that **problems identified in previous annual OTSI bus fire safety reports with the location or accessibility of the fire extinguisher, and/or the driver training on the use of extinguishers may still exist.** However, reduction in the use of extinguishers could also be a consequence of 1) poor access to the source of the fire, or 2) bus drivers noticing fires too late to be able to attempt to use the fire extinguishers safely.

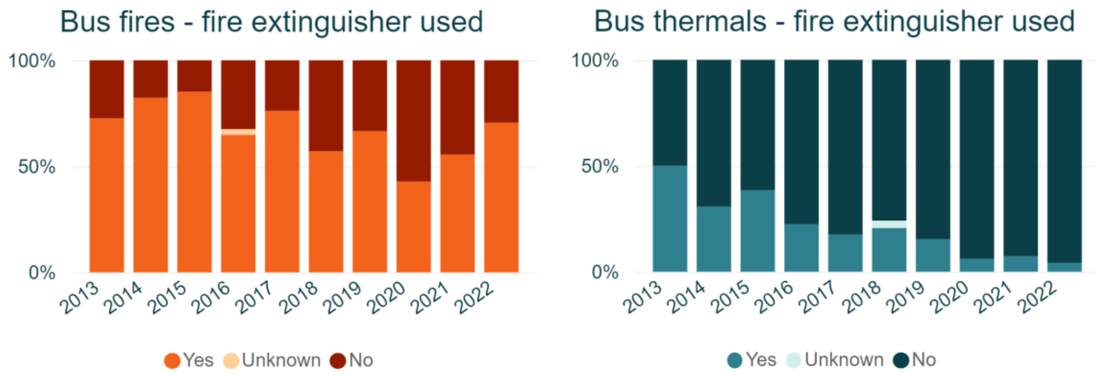

Figure 33: The percentage of the bus fire and thermal incidents where the portable fire extinguisher was used.

OTSI also analysed the effectiveness of portable fire extinguishers in eliminating bus fires. As shown in Figure 34, in the last decade, fire extinguishers were successful in eliminating flames in 77% of bus fires in which they were used. However, yearly distribution of this graph (Figure 34) showed that the success rate has been declining over the years (correlation coefficient of the unsuccessful fire extinguisher use = 0.73, indicating strong positive correlation).

The above findings suggest **1) the appropriateness of the type and location of the onboard portable fire extinguisher, and driver training in their efficient use need to be reviewed, and 2) additional fire detection and suppression technologies should be explored for buses.**

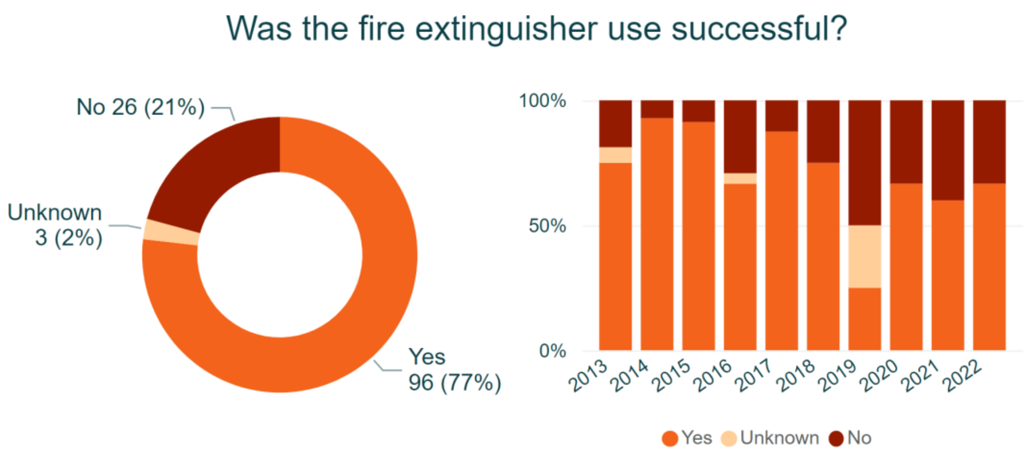

Figure 34: Overall i.e. from 2013-2022, (left) and yearly distribution (right) of the percentage of bus fire incidents where the use of the fire extinguisher was successful in eliminating the flames.

Engine bay fire suppression systems

EBFSS detect fire or heat within a bus engine bay and activate a fire retardant to suppress a fire if present, thereby providing more time for passengers to evacuate, and assist in limiting the damage caused to the vehicle in the event of a fire.[27]

Since 2015, all new TfNSW contracted buses have been fitted with EBFSS. In addition, as part of the EBFSS rollout project which ended in August 2017, all metropolitan and outer metropolitan buses were retrofitted with EBFSS.[28] Several past OTSI annual bus fire safety reports have detailed incidents where activation of the EBFSS had either prevented the fire from spreading or held the fire until NSW fire and rescue arrived, which limited the severity of the damage to the bus. In this report, OTSI analysed the data on EBFSS activations over the last decade, to determine its effectiveness.

Since EBFSS are fitted in the engine bay, only those incidents were selected for analysis in this section, which 1) originated in the engine bay, and 2) had an EBFSS fitted in the bus at the time of the incident. As shown in Figure 35, from this subset, **56% of bus fires and 9% of bus thermals, activated the fitted EBFSS.** Of the 19 bus fires originating in the engine bay where EBFSS were activated, 9 buses sustained minor or smoke damage, 6 major damage and 4 were destroyed. Of the 15 fire incidents where EBFSS were fitted, but not activated, 14 buses sustained minor damage and 1 major.

Although a larger dataset will allow a more conclusive analysis, initial indications suggest that **1) the threshold for the activation of the EBFSS should be reviewed, 2) their design, installation, location and maintenance should be reviewed, and 3) additional fire mitigation and/or fighting technologies should be investigated for buses.** OTSI has also previously highlighted the importance of proper testing, servicing, and installation of EBFSS in buses.[29] Fire mitigation advisory published by Bus Industry Confederation in 2014[19] lists a wide range of fire mitigation measures and recommendations, some of which (such as TMS and EBFSS) have been implemented, but many are still pending.

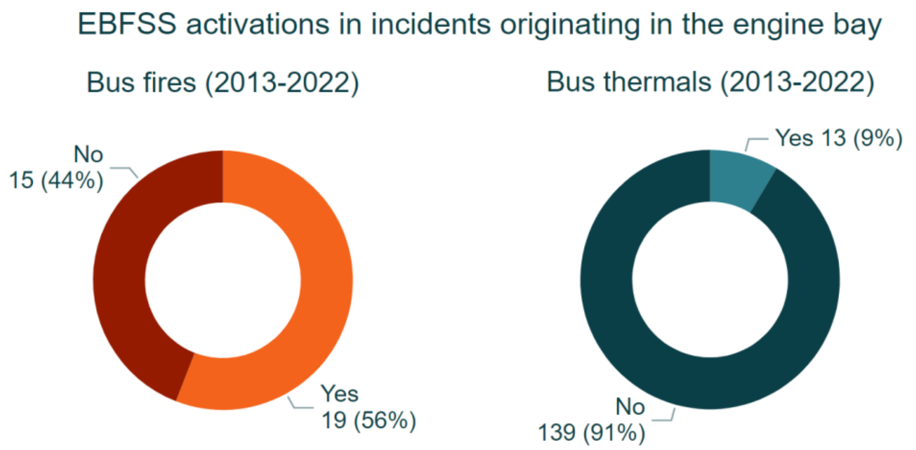

Figure 35: The number of EBFSS activations in the bus fire and thermal incidents originating in the engine bay area of the buses fitted with EBFSS from 2013-2022.

[27] https://www.transport.nsw.gov.au/news-and-events/media-releases/safety-boost-for-bus-customers

[28] https://www.transport.nsw.gov.au/newsroom-and-events/articles/rollout-of-bus-fire-suppression-completed

[29] Safety Advisory: commissioning and servicing of bus and coach fire suppression systems, SA03/22, 2022, https://www.otsi.nsw.gov.au/safety-advisory-sa0322-commissioning-and-servicing-bus-and-coach-fire-suppression-systems

Tyre monitoring systems

Many NSW buses are also fitted with TMS, commonly referred to as tyre pressure monitoring systems. These systems continuously monitor tyre pressure and temperature and transmit this information wirelessly to a dash mounted screen, providing a visual and audible alert for rapid deflation, under inflation, over inflation and excessive heat in the tyres. OTSI started collecting data on the buses fitted with TMS as part of the bus fire and thermal incident reporting in 2019.

To determine the effectiveness of TMS in detecting and alerting drivers of fire and thermal incidents, OTSI analysed data from 2019-2022. Since TMS can only assist in the detection of incidents originating in the wheel well area of the bus, only this subset of incidents was considered in the analysis.

As shown in Figure 36, **in buses fitted with TMS, 19% of thermals originating in the wheel well since 2019 caused TMS activations.** The number of bus fires in this selected subset was low (5 fires). However, of these 5 incidents, only 1 activated the TMS. It should be noted that in a majority of TfNSW contracted buses, TMS are only fitted to the rear wheels of the bus and the data on whether a fire/thermal incident originated in the front or rear axle is not comprehensive. Also, it is acknowledged that thermal incidents caused due to brakes can take a long time to heat the wheel to activate the TMS alarm.

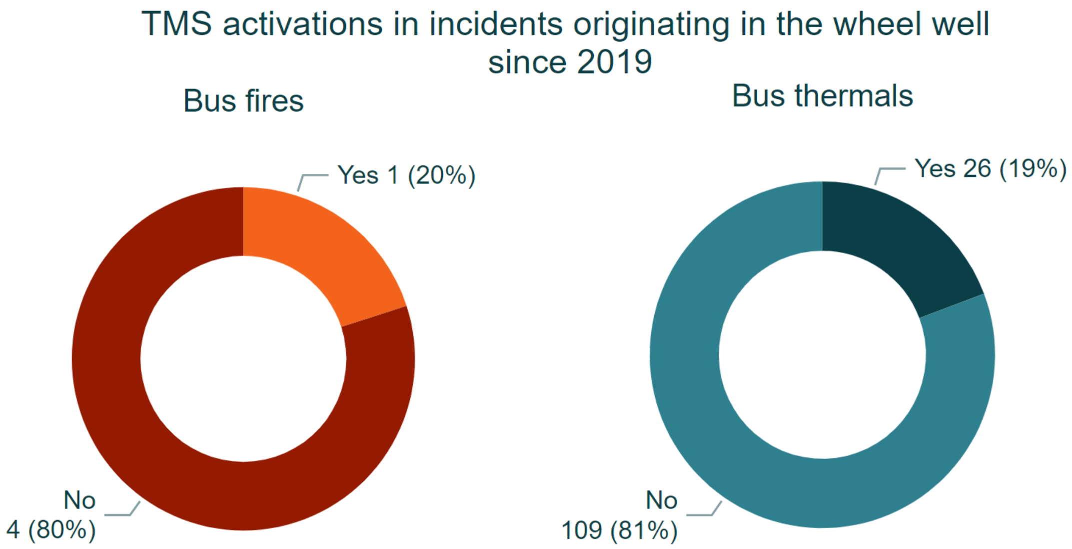

Figure 36: The number of activations of the tyre monitoring systems in the incidents originating in the wheel well since 2019. These numbers only reflect those incidents where TMS were fitted in the bus at the time of the incident.

Although the above analyses should be repeated on incidents originating in the rear wheel well area of the bus, and for statistical relevance a much larger dataset is required, the above findings suggest that **existing fire and smoke detection technologies should be reviewed, and additional solutions should be explored to improve bus fire safety.** For example, detecting overheating brakes through strategically placed sensors may be a better solution to detect wheel well fires than monitoring tyre temperatures through TMS.

Method of detection

To further explore this need for innovation in fire and thermal detection in buses, OTSI analysed how bus fire and thermal incidents were detected in the last 10 years. As shown in Figure 37, ~90% of bus fires and ~93% of bus thermal incidents were detected by people – be it bus drivers, passengers or other motorists. Of 816 bus fire and thermal incidents in the last 10 years, only 50 incidents were detected by fire alarms installed in the buses. Together, this finding along with the findings from the TMS activations **highlight the need for a review of the existing fire and smoke detection technologies and exploration of newer solutions that can lead to early fire detection.** Early detection allows for quicker implementation of fire mitigation solutions, reducing risks to passengers and reducing damage to buses.

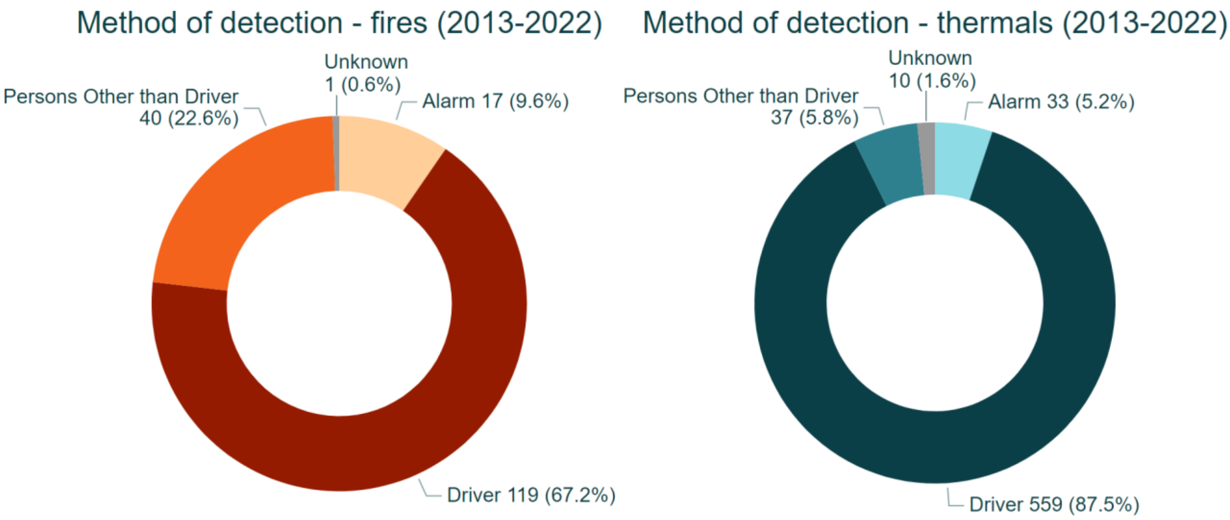

Figure 37: An overall distribution of how bus fire and thermal incidents were first detected in the last 10 years. “Persons other than driver” include passengers, and other motorists.

Benchmarking NSW

In this section, the NSW bus fire incidence rates have been compared nationally and internationally. Benchmarking can assist in informing policy decisions and improving bus fire safety through identification of potentially unique causes of fire, and shared bus fire safety learnings. This section serves as an initial step towards benchmarking analysis.

NSW compared nationally

OTSI obtained information on the total number of bus fires in 2022 in Victoria (from Bus Safety, Safe Transport Victoria), Western Australia (from the Department of Fire and Emergency Services, Government of Western Australia) and Tasmania (from Passenger Transport, Department of State Growth). To obtain a comparison with NSW bus fire incidence rates, the total number of bus fires in every state was normalised to their respective bus fleet numbers. In order to have the same classifications, and same estimation techniques across all states, the national estimates from BITRE were used for the total number of buses in every state as at 31 January 2022 (the estimates as at January 2023 had not been published at the time of this analysis).[30]

As shown in Table 1, **of the four Australian states, NSW had the most fires per 10,000 buses in 2022,** followed by Victoria.

Table 1: The total number of buses in the bus fleet, and bus fires in NSW, VIC, WA and TAS in 2022. The total bus numbers are based on the BITRE estimates as at January 2022, and the number of bus fires in 2022 was obtained from OTSI (NSW), Safe Transport Victoria (VIC), Department of Fire & Emergency Services (WA), and Department of State Growth (TAS), respectively.

State	Total buses	Bus fires	Bus fires per 10,000
NSW	24287	17	7.0
VIC	18328	7	3.8
WA	13538	3	2.2
TAS	2627	0	0.0

NSW compared internationally

OTSI also benchmarked bus fire incidence rates in NSW against international evidence. The most important requirement for such comparisons is the availability of accurate data (both for incidence and fleet size) and comparable classification systems. OTSI's research found that England has maintained an excellent national database for all the bus fleet information,[31] and bus fires.[32]

[30]Bureau of Infrastructure and Transport Research Economics (BITRE) 2022, Motor Vehicles, Australia, January 2022 (First Issue), BITRE, Canberra, Australia. https://www.bitre.gov.au/sites/default/files/documents/BITRE-Motor-Vehicles-Australia-2022-FirstIssue.pdf.

[31] Table titled "FIRE0302" from https://www.gov.uk/government/statistical-data-sets/fire-statistics-data-tables#non-dwelling-fires-attended.

[32] All the tables available from https://www.gov.uk/government/statistical-data-sets/bus-statistics-data-tables.

From these datasets, England's bus fire incidence rates were calculated per 10,000 public buses, and per 100M passenger bus journeys over the last decade[33] and compared to NSW's incidence rates,[34] as shown in Figure 38. Barring the caveats listed in footnotes 33 and 34**, NSW's bus fire incidence rates normalised to the number of buses were found to be consistently and significantly lower than England's over the last decade.** However, the **incidence rates were found to be comparable when considered per 100M bus passenger trips.** Note that the ratio of bus passenger trips per bus was found to be significantly higher for England compared to NSW's bus Opal trips per bus, likely a consequence of the population difference between England and NSW. Figure 38 also suggests that there may be a positive correlation between bus fire incidence and bus loads (since England's buses have a significantly higher bus load and equally higher fire incidence rate per bus compared to NSW). This possibility was also observed and highlighted in the 'Time of day' analysis section.

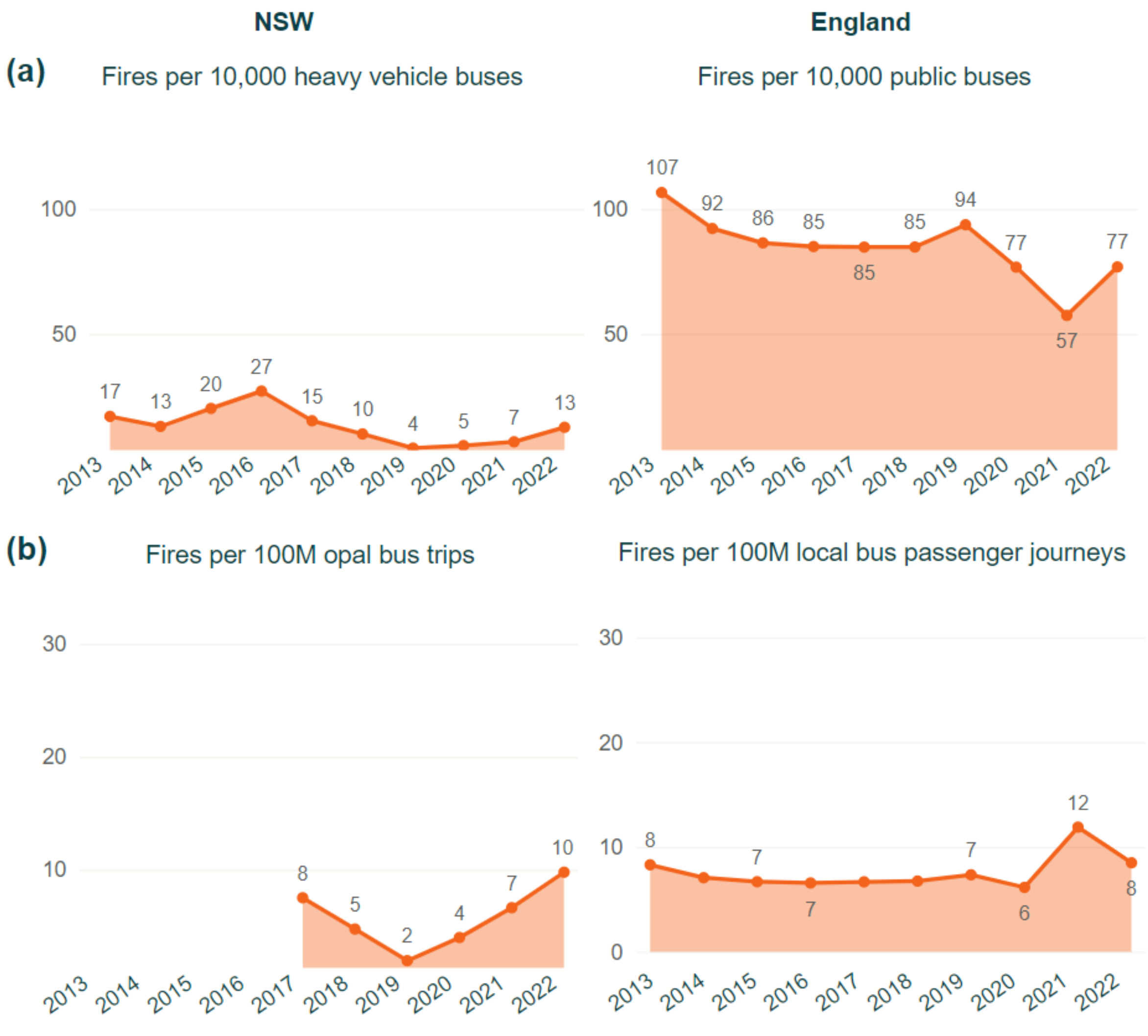

Figure 38 The bus fire incidence rates in NSW and England normalised to the bus fleet and patronage, from 2013-2022. See footnotes 33 and 34 for caveats and considerations.

---

[33] England's bus fire incidence data was available for buses and coaches only, whereas the total number of public buses and passenger bus journeys included buses, coaches and minibuses. Therefore, the normalised incidents rates shown in Figure 38 are likely slight underestimates. In addition, England's data was available for financial years, where NSW's normalized data was in calendar year format. Therefore, 2012-13 financial year has been displayed as 2013 (and so on) in Figure 38.

[34] For NSW, the bus fleet numbers included registered heavy vehicle buses only, and the bus patronage only included opal bus trips. Therefore, the normalised bus fire incidence for NSW in Figure 38 is likely an overestimate.

The benchmarking analysis shows that there are significant differences in bus fire and thermal incidence rates between NSW and other Australian states, and NSW and England. Further investigation into these differences may allow the identification of new, and/or validation of already identified, potential contributing factors to bus fire and thermal incidents. For example, with the identification of bus age as a potential contributing factor in this report (see 'Potential contributing factors' section), benchmarking of the bus fleet age between Australian states may assist in understanding the differences between their respective bus fire incidence rates. Similarly, national and international comparisons of the bus kilometrage, road congestion, average bus loads may provide insights into bus fire and thermal incidents that may be unattainable otherwise. Finally, insights gained from benchmarking can help inform policy decisions and improve bus fire safety through shared learnings and practices.

The benchmarking analysis in this report is preliminary, largely due to the lack of data or restrictive access to data. Consequently, it is recommended that **a national database be set up to register and record all bus fire and thermal incidents, and to provide a consistent bus fleet dataset (registered buses, kilometres travelled, and bus patronage) nationwide. For open and transparent investigation, it is important that such databases are made publicly available.** Having a national database would significantly assist in the investigation, identification and alleviation or maintenance of safety issues related to bus fires and/or thermal incidence.

Recommendations

Based on the analyses and findings of this report, OTSI makes the following six recommendations, with the express understanding that each recommendation may require the cooperation of multiple organisations, including National Heavy Vehicle Regulator, Bus Industry Confederation, and all states and territories' transport and/or bus authorities. In NSW, recommendations 2-6 are addressed to Transport for NSW for their consideration and action. OTSI may be able to assist with preliminary research and advice on all recommendations.

1. Establish a national database to record all bus fire and thermal incidents, and to provide consistent bus fleet data for all states and territories.

Lack of baseline bus fleet data for normalisation and limited statistical relevance due to small bus fire and thermal incident datasets have been cited as limiting factors for diagnostic data analysis throughout this report. Provided the operator reporting protocols and systems are consistent across all states, a national database will resolve these problems by providing a single source of bus fleet data, and a much larger dataset of the bus fire and thermal incidents (compared to NSW only). In addition, as was highlighted in sections 'Potential contributing factors' and 'Benchmarking NSW', a national database will allow investigation and identification of many more potential contributing factors than what has been achieved in this report, and will allow accurate benchmarking across Australia and against other countries.

For open and transparent research and analysis, it is recommended that this database be made available publicly. Further, it is recommended that data classifications in this database be considered carefully so that information on causes and potential contributing factors identified in this report is captured, along with information on other factors such as fuel type, type of emission control technology, type of fire mitigation technology, bus type, route, bus load, and bus maintenance and servicing schedules.

2. Review the average age and age distribution of the NSW bus fleet.

The 'Age of buses' section (under 'Potential contributing factors') highlighted a strong correlation between bus age and bus fire/thermal incidence rates, and a possible correlation between bus age and severity of damage sustained by the bus involved in a fire. In addition, the 'NSW bus fleet' section highlighted that average age of the NSW bus fleet increased in the last few years, reaching a peak in 2022. Therefore, it may be beneficial to reduce the average age of the NSW bus fleet over time.

Further, age distribution analysis in the 'NSW bus fleet' section showed that new bus deliveries to NSW have varied significantly over the years. A major delivery of new buses in a year was followed by much fewer new bus deliveries in the subsequent years. This has resulted in big clusters of buses of a particular age group. As these clusters age, the likelihood of the bus fire and thermal incident increases. Also, it was shown in the 'Year of manufacture' section that buses manufactured in particular years had a higher likelihood of getting caught in a fire or thermal incident. Having large clusters of buses from a particular year of manufacture may present challenges if those batches later present higher risk factors for fires. Therefore, it may be beneficial to review the purchasing patterns and adopt a more consistent approach to maintain a regular delivery of new buses.

3. Explore better and smarter fire and smoke detection technologies for buses.

The findings from the 'Effectiveness of the current interventions' section highlighted the limitations of the current technological interventions fitted in the buses for fire and smoke detection. In particular, only ~6% of the bus fire and thermal incidents in the last decade in NSW were detected by fire alarms and/or smoke detectors. Further, in buses fitted with tyre monitoring systems, 20% of bus fires and 19% of thermals originating in the wheel well area of the bus activated the tyre monitoring systems. Therefore, it is recommended that better and smarter fire and smoke detection technologies are explored for buses. Early fire detection can allow quicker implementation of fire mitigation solutions, leading to lower risk to passengers and reduced damage to buses.

4. Review the appropriateness of the type, location, installation and maintenance of the existing fire mitigation/fighting technologies fitted in the buses. Review driver training into the use of these technologies and ensure rigorous risk assessment.

The 'Effectiveness of the current interventions' section identified several deficiencies in the implementation or use of existing fire suppression technologies fitted in the buses. In particular, the 'Engine bay fire suppression systems' section showed that in buses equipped with engine bay fire suppression systems, only 56% of fires and 9% of thermal incidents originating in the engine bay in the last decade activated the fitted fire suppression systems. Also, as highlighted in the 'Origins and causes' section, engine bay is still the most dominant area of origin for bus fires in NSW. Based on these findings, it is recommended that the threshold for the activation of the engine bay fire suppression systems be reviewed, along with their design, installation, location, and maintenance.

The trends analysis in the 'Portable fire extinguishers' section highlighted that the percentage of bus fires where the response included use of a portable onboard fire extinguisher has declined over the years. Of the incidents where a fire extinguisher was used, the success rate of the extinguisher also declined over the years. Based on these trends, it is recommended that the appropriateness of the type of extinguisher and its location on the bus is reviewed, along with the sufficiency of driver training into the use of onboard extinguishers.

5. Explore additional fire mitigation/fighting technologies for bus fire safety.

Several factors identified in this report have led to the recommendation that additional bus fire mitigation/fighting technologies need to be considered to improve bus fire safety. These include: 1) increasing bus fire and thermal incidence rates ('Bus fire and thermal incidents' section), 2) deficiencies in the existing fire mitigation/fighting technologies ('Effectiveness of the current interventions' section), and 3) lack of technological interventions for fire and thermal incidents originating in the body or wheel well of the bus. Newer fire mitigation/fighting technologies are also required to proactively manage bus fire safety in the changing NSW bus fleet as zero-emission electric and hydrogen buses are rolled out.

6. Review Australian Design Rules and TfNSW procurement panels for buses.

The Australian Design Rules do not mandate automatic fire suppression systems in buses (including coaches). While TfNSW procurement panels require fire suppression systems for the engine bay, they are not required for other areas of the bus such as the body or wheel well. Considering the recent increase in the percentage of body or wheel well originated bus fires (see 'Origins and causes'), fire mitigation interventions for these areas may improve passenger safety. Moreover, coaches without EBFSS and with only one entry or exit door pose a potential risk to passenger safety in the event of a fire.

OTSI bus fire incident investigations have also identified potential problems with the flammability of materials used in the bus and the appropriateness of the fire extinguishers required as part of the Australian Design Rules. It is recommended to investigate these factors, assess the risks involved, and review the standards, TfNSW procurement panels, and Australian Design Rules based on the findings.

Conclusions and future work

Conclusions

The findings of this report highlight the rise in bus fire and thermal incidents in NSW in recent years. The economic impact of these incidents, estimated at $203 million from 2013-2022, underscores the urgency of addressing this issue. Without further action, it is projected that costs over the next decade could reach $265 million.

While there were no fatalities and only four injuries reported in the past decade, the psychological impact on drivers and passengers cannot be ignored. Many drivers reported feeling anxious and had trouble sleeping after the incidents. Some even left the profession.

The report investigated the origins and causes of these incidents, highlighting engine bay as the most common area of origin for bus fires and wheel well for thermal incidents. Electrical faults were found to be the primary cause of bus fires, emphasising the need for improved configuration management, maintenance, and inspection of electrical components. Brake problems were identified as the main cause of thermal incidents, warranting further investigation into targeted solutions.

Bus age, weather conditions and bus year of manufacture were investigated as potential contributing factors. Bus age was found to correlate with increased incidence rates until ~14-16 years old (for fires) and ~10 years old (for thermals). Initial evidence also correlated bus age with increased sustained damage if involved in a fire. These findings emphasised the importance of reviewing the average age and age distribution of the NSW bus fleet. Weather conditions were found to have no effect on the likelihood of a bus fire but could increase the incidence rate of thermal incidents in colder weather. Buses manufactured in 1987 and 2004 were identified to have the highest fire incidence rate and buses manufactured in 2009-2011 the highest thermal incidence rate.

Existing bus fire safety interventions have had a positive impact, saving NSW an estimated $15.5 million and with an additional $19.9 million savings projected over the next decade. However, given the recent rise in incidence rates, several areas for improvement were identified.

Existing fire and smoke detection technologies in buses showed limited effectiveness, with only a small percentage of incidents being detected through the fitted detection systems. Innovation in this area is needed to ensure early detection, allowing for timely implementation of fire mitigation solutions.

The implementation and use of the fire mitigation technologies in buses require review and improvement. Deficiencies were identified in the activation and effectiveness of existing technologies, such as engine bay fire suppression systems and onboard fire extinguishers. Considering that a significant percentage of bus fires and thermals originate in the body or wheel well where no automatic suppression systems are currently installed, the exploration of additional fire mitigation technologies is crucial.

The Australian Design Rules for buses need to be reviewed, especially given the absence of requirements for automatic fire suppression systems. It is also essential to investigate the flammability of materials used in buses with a view to determining appropriate standards, and the effectiveness of fire extinguishers, as identified by previous OTSI incident investigations.

To facilitate comprehensive data analysis and informed decision-making, the establishment of a national database recording all bus fire and thermal incidents, along with consistent fleet data across states and territories, is recommended. This database should be publicly available, promoting transparency and enabling valuable benchmarking and shared learnings.

In conclusion, this report emphasises the need for action to address the increasing incidence rates of bus fire and thermal incidents in NSW. The recommendations outlined in this report provide a comprehensive framework for improving bus fire safety management, including the establishment of a national database, fleet age review, innovation in detection technologies, enhancement of existing mitigation technologies, exploration of new technologies, and a review of relevant Australian Design Rules. Implementing these recommendations will contribute to safer bus operations and enhanced wellbeing of drivers and passengers and reduce the economic impact from bus fire and thermal incidents.

Future work

Several areas have been highlighted throughout this report for further investigation or research. First, the report noted a significant increase in bus thermal incidents due to mechanical problems in 2022 compared to 2021. It also observed a continuous decrease in bus thermals caused by fluid leaks. These findings suggest the possibility of a systemic change, further investigation into which is required to identify contributing factors and learnings for the management of bus fire safety.

The analysis of incident time and benchmarking with England indicated potential correlations between bus load, road congestion, and bus fire/thermal incidence rates. However, more data and analysis are required to confirm these correlations. If confirmed, investigating the mechanical basis behind these correlations could help to identify root causes and to develop fire safety solutions.

Buses manufactured in 1987 and 2004 showed a higher likelihood of bus fires, while those from 2009-2011 had a higher likelihood of bus thermals. Further investigation of these batches could reveal factors contributing to their higher incidence rates and aid in the development of fire safety solutions.

Comparisons between NSW and other Australian states, and NSW and England, highlighted significant differences in bus fire and thermal incidence rates. Investigating these differences, along with the analysis of bus fleet, road congestion, and average bus loads, could help to identify additional potential contributing factors to bus fire and thermal incidents and/or validate already identified factors.Finally, further research is needed to understand the fire safety risks associated with electric batteries and hydrogen fuel cells in new zero-emission buses. This research could help to proactively develop fire prevention, detection, and mitigation solutions for the changing bus fleet.

Appendices

Appendix A – Glossary

Accredited operator - a person accredited under the *Passenger Transport Act (NSW)* to carry on a public passenger service.

Body -the portion of a bus that contains the bus occupant space, and other areas such as the drivers cab and dashboard, air conditioning devices and underfloor storage areas.

Bus – a heavy motor vehicle built or fitted to carry more than nine adults, including the driver. This includes tourist coaches.

Bus fire – an excessive heat incident with visible flames, including explosion or implosion; associated with or impacting bus operations.

Bus thermal – an excessive heat incident with no visible flames, but a likely precursor to a fire.

Engine bay – the part of the bus that contains the engine, or electric motor.

Heavy vehicle bus – a bus with the 'gross vehicle mass' exceeding 5.0 tonnes.

Wheel well – area of the bus including wheels, tyres, axles and braking mechanisms.

Appendix B – Severity level descriptions for bus damage

Destroyed – Significant destruction to one or more large sections of the bus. Repairs or replacements are either not possible or not economically viable.

Major – Damage to a large section of the bus (e.g., the entire engine bay) or multiple parts. Major repairs or replacements required. But it is still economically viable to do so.

Minor – Damage to a part or small sections of the bus. Minor repairs or replacements required.

Smoke damage – Cosmetic damage due to smoke, such as smoke stains. No mechanical repairs required.

Nil damage – No physical damage to any part of the bus. No repair or replacements required.

Appendix C – Approach to the assessment of economic costs and benefits

This section sets out the approach that was used to estimate the economic costs of bus fire and thermal incidents to New South Wales. The approach to estimating the benefits of the safety interventions and initiatives to reduce the incidence of bus fire and thermal incidents is also outlined.

Types of costs associated with the incidents

The factors that directly contribute to the economic impact of bus fire and thermal incidents include:

- **injuries and fatalities –** the economic cost of injuries and fatalities can be quantified based on measures of the statistical value of life and injury,[35] which are based on estimates of the willingness of society to pay to reduce the risk of death and injury for individual passengers;
- **damage to buses** – the damage costs for a specific incident will be related to the severity of the incident, with bus fires likely to have higher damage costs compared to thermal incidents. The costs of repair or replacement in this report have been based on historical observations of repair costs and depreciated bus values;
- **emergency service responses –** bus fires and thermal incidents at times require the attendance of Fire & Rescue, police, ambulance, and other resources to resolve the fire or thermal incident itself, to control traffic flow, and to remove the bus from obstructing the traffic. The cost of emergency response falls on the community more generally through its funding of these response services, and has been estimated in this report as a cost of response, moderated by the portion of incidents of a specific severity attracting an emergency service response; and
- **direct travel delays –** passengers on the affected bus will need to find replacement transport, which can be inconvenient, take time and lead to travel delays. While the value of these travel delays may vary between passengers, delays impose an economic cost on individual passengers though the amount of time needed to find alternative transport that could be avoided in the absence of bus fires and thermal incidents.

In addition to these direct impacts, a bus fire or thermal incident has a flow-on impact on other transport network passengers and commuters. These indirect flow-on impacts include:

- **indirect travel delays –** a bus fire or thermal incident will typically cause the bus experiencing an incident to be taken out of service for inspection, or repair or replacement. This can lead to service cancellations, which affects the capacity of the bus network to deliver services to downstream bus passengers. This translates to delays for downstream passengers and imposes an economic cost[36] in the form of time organising and waiting for alternative transport that could be avoided in the absence of bus fire and thermal incidents; and
- **road congestion** - bus incidents adversely affect traffic flows on the road network at least until the bus causing obstructions is removed from the road. Consequently, bus incidents can contribute to slower journeys and delays for commuters and imposes an economic cost on commuters' time that would be avoided in the absence of bus fires and thermal incidents.

---

[35] Best practice regulation guidance note: Value of statistical life, Department of the Prime Minister and Cabinet, Office of Best Practice Regulation, August 2022. https://oia.pmc.gov.au/sites/default/files/2022-09/value-statistical-life-guidance-note.pdf

[36] The cost of travel delays and congestion in this report is based on the value of travel time and an inconvenience multiplier sourced from Transport for New South Wales (*Economic parameter values*, version 2.0, June 2020, pp 10, 13) multiplied by the expected delay for travellers and commuters.

Note that the costs associated with the psychological impact and damage to other property such as road infrastructure have not been included in the economic analysis described in this report due to the lack of data.

Effect of incident time

While estimating the economic impact of bus fire and thermal incidents in NSW, the time at which an incident occurred has a material effect on the cost of that event. For example, incidents that occur during peak traffic periods cost more than incidents occurring at other time periods, largely due to the flow-on economic costs relating to delays for downstream bus passengers and other road users.

Figure 39 presents the distribution of bus fire and thermal incidents from 2013-2022 by the cost incurred per incident. The data shows that the distribution of the costs for both fire and thermal incidents is concentrated around lower cost incidents with 80 per cent of incidents costing less than $300,000 per event and 97 per cent of incidents costing less than $500,000 per event over the last decade.

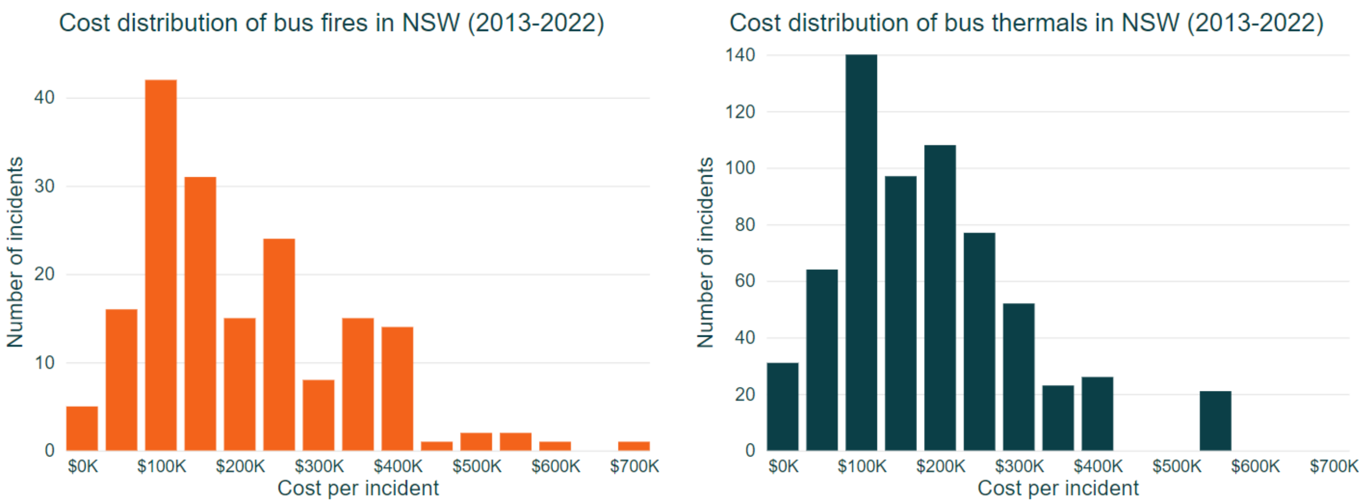

Figure 39: Distribution of bus fire and thermal incident costs showing how many incidents incurred how much cost in NSW from 2013-2022. The costs are given in the present value terms and expressed in 2022 dollars. Note that the *x*-axis represents the range of costs, e.g., $0K represents incidents costing $0 – $50,000.

The highest cost fire incident involved a destroyed bus in 2017 at 7:43 am during peak hour traffic in Inner West Sydney. The cost of this fire incident was estimated to be approximately $700,000, primarily driven by the cost of bus damage, flow on delays for travellers and congestion costs. The highest cost bus thermal incident occurred in 2022 in Kellyville at 7:04 am during peak hour traffic. The cost of this event was estimated to be approximately $590,000, driven by the widespread cost of disruption from cancelled services and increased congestion from this event.

Estimating the economic costs of bus fires and thermal incidents

Absent specific information on the historic costs of previous bus fire and thermal incidents, these costs have been approximated based on the key cost drivers related to each incident. Specifically, the economic costs of these incidents were estimated by considering:

- **the severity of an incident** – there are five levels of severity for each of the two categories of incidents (i.e., fire or thermal). The intensity of a fire or thermal event has cost implications for the level of emergency service response, risk of injury or fatality, and the extent of replacement or repair costs that are incurred to rectify bus damage. For example, thermal events typically involve negligible damage to buses or adjoining infrastructure whilst major fires may require the complete replacement of a bus and repairs to road infrastructure where the incident occurred.
- **the location of an incident** – there are 27 bus contract regions considered in the modelling to reflect variations in the bus service density of different locations that affect the number of passengers and the delays that may occur. An incident in more densely serviced areas is likely to result in greater disruption to bus passengers and commuters, while an incident in less densely serviced areas will likely affect less bus passengers and commuters.
- **the time of day** – the modelling decomposes each 24-hour day into twelve 2-hour blocks. This allows estimates for each 2-hour block to vary by the number of passengers and commuters affected by an incident. Incidents during peak periods are likely to have significantly larger disruptive effects due to the larger number of bus passengers and commuters, compared to off peak periods of the day.

It follows that there are 3,240 combinations[37] of incident type (fire, thermal), severity (five levels), location (27 bus contract regions), and time of day (12 two-hour blocks) that were included in the economic models used to estimate the costs of the bus fire and thermal incidents in NSW. The cost for each incident which varies based on the incident type, severity, location, and time of day is summed to derive a total cost estimate over a relevant time period (e.g., one year).

In terms of modelling timeframes, the analysis was organised into two distinct periods:

- **the ten-year period commencing 2013 and ending 2022** – for this period, the historic economic costs are estimated based on observed incidents.
- **a projection period commencing 2023 and ending 2032** – forecast incidents are combined with estimated economic costs to project the expected future economic costs of bus fires and thermal incidents.

Projecting the bus fire and thermal incidence

To understand how the activities of OTSI and others to prevent bus fires have reduced the number of bus fire incidents, OTSI has developed projections of:

- the number of bus fires that were expected over the period 2013 to 2022, based on the average incident rate between 2013 and 2015;
- the number of bus fires expected over the period 2023 to 2032, based on the average incident rate between 2013 and 2015;
- the number of bus fires expected over the period 2023 to 2032, based on the average incident rate observed in 2022; and
- the number of thermal incidents over the period 2023 to 2032, based on the average incident rate observed in 2022.

[37] 2 incident types × 5 severity levels × 27 locations × 12 two-hour blocks = 3,240 incident type, severity, location, and time of day combinations.

The 2022 incident rates have been used for the projections of bus fires and thermal incidents for the period 2023 to 2032 to provide a benchmark for assessing improvements related to the 2022 rate, into the future.

The incident rates are combined with projections of kilometres scheduled to determine the total number of incidents of bus fires and thermal incidents (as relevant). Specifically:

Number of incidents = incident rate per kilometre travelled × kilometres scheduled

Once the number of incidents is known, the cost of incidents can be estimated by applying cost assumptions that quantify each incident in monetary terms.

The difference between the costs estimated based on the projected bus fires over the 2013 to 2022 period, and the observed costs reflects the estimated costs avoided over the ten-year period, as a consequence of activity to lower the number of incidents. These interventions to reduce the risk and severity of bus fires and thermal incidents include:

- increased focus on maintenance;
- investigations and reporting to identify opportunities for safety improvements;
- issuing of safety notices;
- communication with operators;
- developing an improved safety culture amongst operators; and
- bus fire engine suppression systems.

Figure 40 sets out the projections of the number of incidents of bus fires under the base case (i.e., based on the incidence rate observed over the period 2013 to 2015), and the intervention case (based on the observed number of incidents until 2022 and the projected bus fire incidents from 2023 onwards).

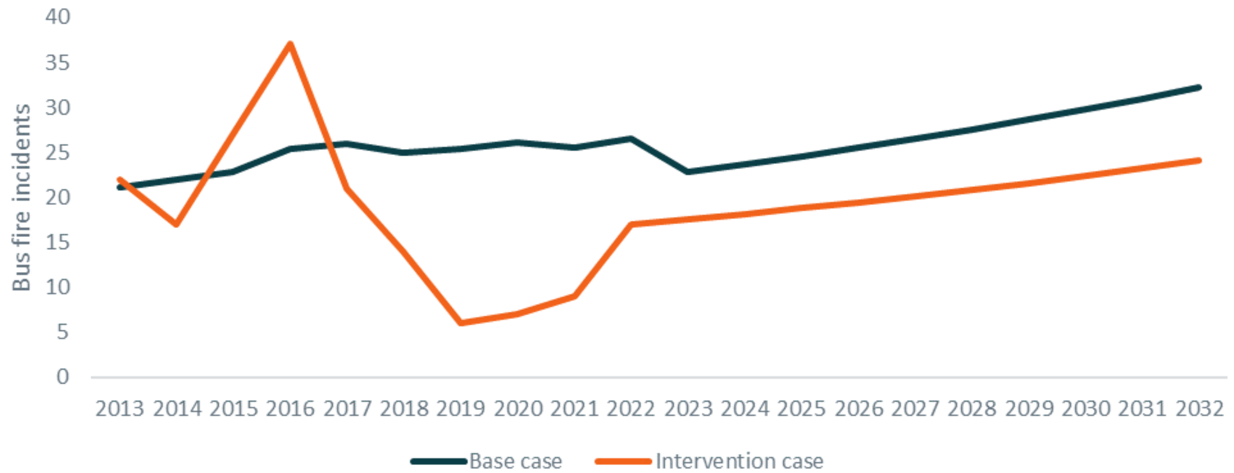

Figure 40: Number of bus fire incidents under the base case and intervention case

A base case for thermal incidents for the period 2013 to 2022 has not been determined for the purposes of the analysis, due to the difficultly in establishing a reasonable incident rate benchmark to use. This reflects increasing number of observed thermal incidents which likely largely reflects improved reporting over the period. Therefore, the focus has been on the cost of observed thermal incidents during the 2013 to 2022 and projecting the number of these incidents across the 2023 to 2032 period.

Office of Transport
Safety Investigations

Street address:

Level 17
201 Elizabeth Street
Sydney NSW 2000

Postal address:

PO Box A2616
Sydney South NSW 1235

T: 1800 180 528
E: transport.safety@otsi.nsw.gov.au
W: otsi.nsw.gov.au