Bus fires in Sweden 2005 - 2013

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SP Sveriges Tekniska Forskningsinstitut

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Abstract

The Swedish Civil Contingencies Agency's (MSB) fire database and statistics form the framework for the national statistics of all fires occurred in Sweden during each year. The data base is based on incident reports from the Fire Rescue Services (FRS). Since 2005, bus fires have separate category in the template for the FRS incident report. The purpose of this survey was to map bus incidents related to fire in commercial traffic between 2005 and 2013. The study includes a total of 1255 records spread over nine-year period. The average number of incidents per year related to fire between 2005 and 2013 was 104, which corresponds to 0.73 % of the buses in the commercial traffic. Cause of incidents has not been possible to map due to limitation in the data material. However, the study shows that most fire incidents originate in the engine compartment (61%), and that the wheel well is the second most common origin area of incident (20%). The study also shows that the bus drivers and staff have a very significant role in the initial stage of the fire-related incidents. Bus drivers extinguished the fire in 26 % of the cases prior to FRS arrival to the accident site.

Key words: Bus, coach, commercial traffic, fire, statistics, origin

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Acronyms

DSB - Norwegian Directorate for Civil Protection

FMCSA - Federal Motor Carrier Safety Administration

FRS – Fire and Rescue Service

MSB – Swedish Civil Contingencies Agency

SCB – Statistics Sweden

SP – SP Technical Research Institute of Sweden

Trafi – Finnish Transport Safety Agency

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Summary

The Swedish Civil Contingencies Agency's (MSB) fire statistics and database form the framework for the national statistics of all fires occurred in Sweden during each year. The data base is based on incident reports from the Fire Rescue Services (FRS). Since 2005, bus fires have a separate category in the template for the FRS incident report. The purpose of this survey was to map bus incidents related to fire in commercial traffic between 2005 and 2013, i.e. to further examine correlations and trends for specific parameters over time as well as to provide suggestions for further studies. Parameters examined were:

- Number of bus incidents related to fire
- Origin of incident
- Extent of incident upon FRS arrival to accident site
- FRS fire-fighting actions
- Extinguishing effort prior to FRS arrival to accident site
- FRS response and operation time

The study includes a total of 1255 records spread over a nine-year period. The data material was processed in a repetitive process in order to obtain relevant information. Loss of the records was 26 %, partly due to the study's limitation to commercial traffic as well as due to number of incidents being registered incorrectly in the bus category. The average number of incidents per year related to fire between 2005 and 2013 was 104, which corresponds to 0.76 % of the total number of buses in the commercial traffic during the same period. The highest number of incidents was recorded in 2006 with 130 cases; and fewest in 2012 with 88 cases and in 2013 with 81 cases. However, studying the whole period it is difficult to make a definitive conclusion on a decreasing trend regarding fire-related bus incidents.

In 61 % of the cases the incident originated in the engine compartment and in 20 % of the cases the incident originated in the wheel well. In 14 % of the cases the data was too flawed to obtain the information regarding origin area; in the remaining 5 % the incident originated inside the bus or in other area.

Flashover occurred in 7 % of all the registered incidents. The highest number of cases was registered in 2009 with 13 cases and in 2012 with 10 cases. It is not possible to read out an obvious trend regarding the flashover fires.

FRS carried out fire-fighting action in 55 % of the call outs between 2005 and 2013. In 73 % of these cases the FRS had to perform extinguishing action and in 27 % of the cases FRS conducted only cooling of the affected area.

The survey shows that the bus drivers and staff have a very significant role in the initial stage of the fire-related incidents. Bus drivers extinguished the fire in 26 % of the cases prior to FRS arrival to the accident site.

1 Introduction

1.1 Background

This report is a part of the research project *Fire detection & fire alarm systems in heavy duty vehicles- research and development of standards and guidelines* coordinated by SP Technical Research Institute of Sweden. Major aim with the project is to develop a new standard for how fire detection and alarm systems should be tested for heavy duty vehicles in a secure and optimized manner. The category of heavy duty vehicles includes various vehicle types such as buses, mining and construction equipment and trucks. However, the extent of this report is limited to study only bus and coach fires in the commercial traffic in Sweden.

Latest mapping of bus fires in Sweden was made in 2006 by SP; the mapping covered the period between 1996 and 2004. In order to obtain an overall picture, a brief review of commercial bus transport between 2005 and 2013 as well as results from previous survey of bus fires in Sweden is presented in the Sections below.

1.1.1 Commercial bus transport in Sweden

Between 2005 and 2013 the number of travels by bus accounted for over 50 percent of all local and regional public travels. During the same period, the number of passenger kilometres has increased by 12 percent, from 5.764 million to 6.573 million kilometres [1]. Perhaps the most interesting fact in accordance to this report is development of number of vehicle kilometres. More specifically, a single bus has on average travelled a distance of 63 096 km in 2013, which is more than any other vehicle type. As a comparison, it is approximately four times more than a car and over 30 % more than a heavy truck [2].

The numbers in Figure 1 are based on the number of buses in commercial traffic at some point during each year; i.e. newly registered and deregistered buses at some point during the year as well as buses that are decommissioned parts of the year are included [3]. The figure shows how the total number of buses in commercial traffic been rather stable, but overall has increased from 13 405 to 13 883 between 2005 and 2013.

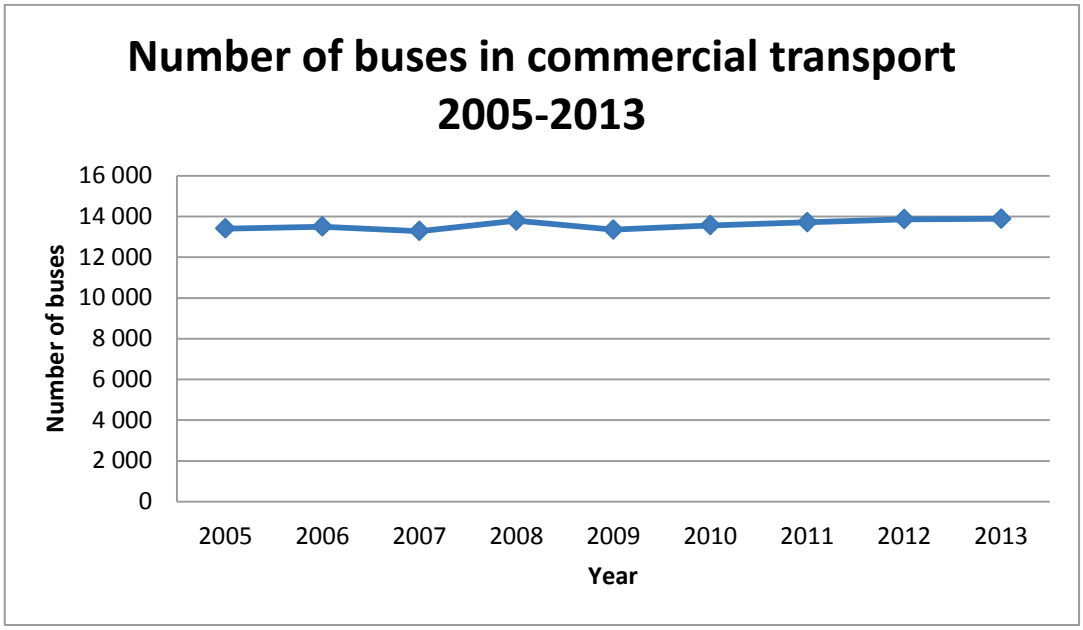

Figure 1 Number of buses in commercial transport 2005 - 2013. (Trafikanalys, 2014b)

1.1.2 Buss fires in Sweden 1996 - 2004

On behalf of the Transport Administration in Sweden, SP Technical Research Institute of Sweden conducted a survey of bus fires between the years 1996 - 2004 [4]. Material for the survey was collected from insurance companies, bus manufacturers, bus companies and Statistics Sweden (SCB). The basis for the SCB database was mainly reports from the FRS. Before 2005, bus fires had no separate category in the FRS incident report; instead these incidents were registered in the category *Other vehicle fires*. In the report, an assessment is made that 90-95 percent of all reported bus fires are represented in the data material used for the study. On average 122 fires per year were registered between 1996 and 2004 according to the SP report. A significant increase in the number of bus fires was noted between 1998 and 2004. Two changes introduced for buses in Europe in 1996 are given as a plausible explanation for this, namely the reduction of the maximum allowed driving noise levels from 83 to 80 dB and the new emission standards. These changes led to higher temperatures in the engine compartment of buses and thus may have contributed to higher probability of fire [4].

In addition to reported cases, the report also gives an estimate of unreported cases of bus fires based on interviewing people with experience in the vehicle and insurance industry. Figure 2 presents the results from SPs report with reported cases and estimation of unreported cases.

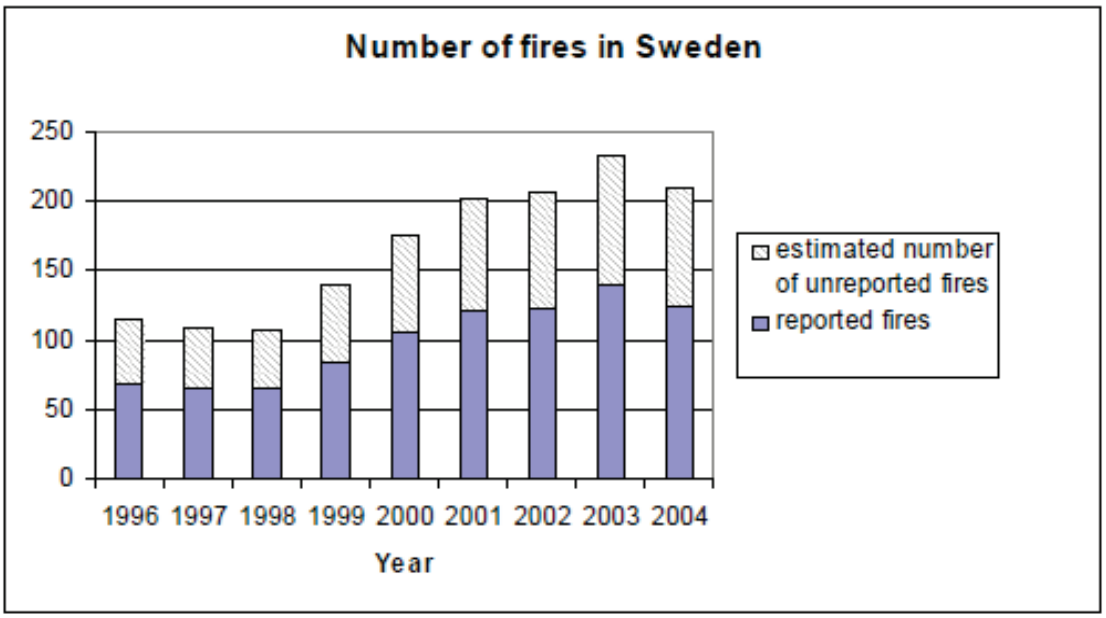

Figure 2 Number of bus fires 1996 - 2004; reported and estimation of unreported fires [4]**.**

The report also identifies cause of fires in the cases of the reported records. In 40 % of the cases the cause of the fire was unknown, and in 31 % the cause was an unspecified technical problem. The distribution of other causes was: electrical failure 10 %, leakage, 7 %, friction 6 % and arson 6 %. The origin area of fire was not investigated in this survey.

1.2 Objective

The objective of this report is to carry out a survey on the incidents related to bus fires in commercial traffic in Sweden between 2005 and 2013; based on data material from MSB. Identified specific parameters are:

- Number of bus incidents related to fire
- Origin of bus incidents related to fire
- Extent of incident upon FRS arrival to accident site
- FRS fire-fighting actions
    - How often?
    - Type of action?
- Initial extinguishing efforts prior to FRS arrival to accident site
    - How often?
    - Who or what performed the initial effort?
    - Effect of the initial effort?
- FRS response and operation time

1.3 Limitations

The report is limited to only examine bus and coach fires in commercial traffic in Sweden. The data material for this report is entirely based on the MSB´s database on bus fires between years 2005 - 2013. Bus manufacturers, insurance companies and bus companies are not objects for examination in this report. In addition to above listed limitations, this report does not take into consideration the number of potential unreported cases.

1.3.1 Limitation of the data material

Starting in 2005, the bus fires got a separate category in the rescue incident reporting. All data from the incident reports is collected in a joint database at the Swedish Civil Contingencies Agency (MSB) and form the framework for the national statistics of all fires.

The template for the incident report is digitalized. The incident report is filled in by the incident commander after the completion of an operation. The report template consists of different variables, some of which are automatically registered and the rest are filled in manually. The variables relevant for this report registered automatically are:
- *Town and county*
- *Date and time*
- *Response time and total operation time, etc.*

Examples of manually registered variables relevant for this report are:
- *Type of fire (e.g. building, vehicle, forest etc.)*
- *Cause of fire*
- *The type of firefighting action made by FRS*
- *Which and what quantities of extinguishing agent was used*
- *Extent of damage to property*
- *Accident sequence, etc.*

Under the variable *Accident sequence* space is given for the incident commander to register all relevant facts and course of events that occurred during the accident. The template for incident reporting is thus in theory designed in a way so that all fire related

information can be archived in a descriptive and detailed way. However, the accuracy and detail of the reports registration varies. Some reports are very carefully and correctly completed, which makes it easy to extract all the relevant information. Certain number reports are not complete, resulting in a lack of documentation where relevant details of the accident could not be obtained. In a few cases, no information could be obtained regarding the accident.

1.3.1 Bus category included in the study

The report is limited to buses and coaches in commercial transport. The delimitation is made in order to more clearly analyze the extent of the fires that occur where most people are affected and where the largest overall impact can be made by improving the fire safety. Buses in commercial traffic are divided according to how much space there is for standing passengers. City bus, highway bus and coach are the three main types of buses. They can also be divided into different classes according to the following [2]:

- Class I - city bus: a vehicle of this class has seats as well as spaces for standing passengers.
- Class II - highway bus or coach: a vehicle of this class can have spaces for standing passengers.
- Class III – coach: a vehicle of this class has no space for standing passengers.

Due to the fact that the information regarding the bus classes is not apparent from the incident reports, no distinction between the classes is made in the report. For the same reason no distinction is made between buses with respect to fuel type.
For simplicity, the studied objects will hereinafter be referred to simply as buses in this report.

2 Method

MSBs database on bus fires between 2005 and 2013 consists in total of 1255 records. Specific parameters that correspond to the objective of the stated purpose were created in order to extract relevant information from incident reports. Parameters and explanations for what they represent are listed below:

- **Bus incident** – Indicates whether it was in fact an incident involving a bus in commercial traffic or an incident that belongs to another category of vehicle.
- **Initial nature of the incident** – Indicates nature of the incident and is divided in two categories, fire and smoke incident.
- **Origin area** – Indicates the specific area in which the incident originated.
- **Extent of the incident at FRS arrival** – Represents the extent of the incident upon the FRS arrival to the accident site.
- **FRS performs action** – Represents whether the FRS performed an action or whether the action was not required. An action could be that the FRS uses their equipment to extinguish fire or cool hot spots.
- **Type of action** – Represents which type of action FRS performed.
- **Action prior to FRS arrival** – Represents whether an extinguishing effort was performed prior to FRS arrival.
- **Effect of the initial action prior to FRS arrival** – Represents the impact and efficiency of the effort performed prior to the FRS arrival, e.g. by the bus driver.
- **Response time** – Represents the time from receiving the alarm to FRS arrival to the accident site.
- **Operating time** – Represents the time from receiving the alarm to FRS completing the operation and leaving the accident site.

Three of the created parameters correspond exactly to the original variables in the template for incident report, namely *FRS performs action*, *Response time* and *Operating time*. These data were thus very easy to obtain from the incident reports. Remaining of the parameters had no exact matching variable in the incident reports. Extraction of data for these parameters was therefore possible only in cases in which this information was explicitly revealed under the variable *Accident sequence* in the incident reports. Different categories were defined within each parameter. Explanations for the category definitions are presented in the context of each result section. Each of the 1255 records was processed individually, repeating the process several times to extract the relevant information.

3 Results

The studied parameters, defined and described in the Section 2 are presented in depth in each respective result section. The results are presented in graphical format; the tables with exact numbers are found in the Appendix A.

3.1 Bus incidents

Minibuses and cars registered in the bus category, as well as re-ignition cases (i.e. these cases have already been registered once and are not regarded as a new accident) and occasional duplicates are removed from the statistics. Incidents involving scrap buses and buses converted into mobile homes are excluded from the survey due to reports limitation to commercial transport. The results show that average shortfall for the studied period is 26 %. The number of bus incidents related to fire between years 2005 - 2013 is illustrated in Figure 3.

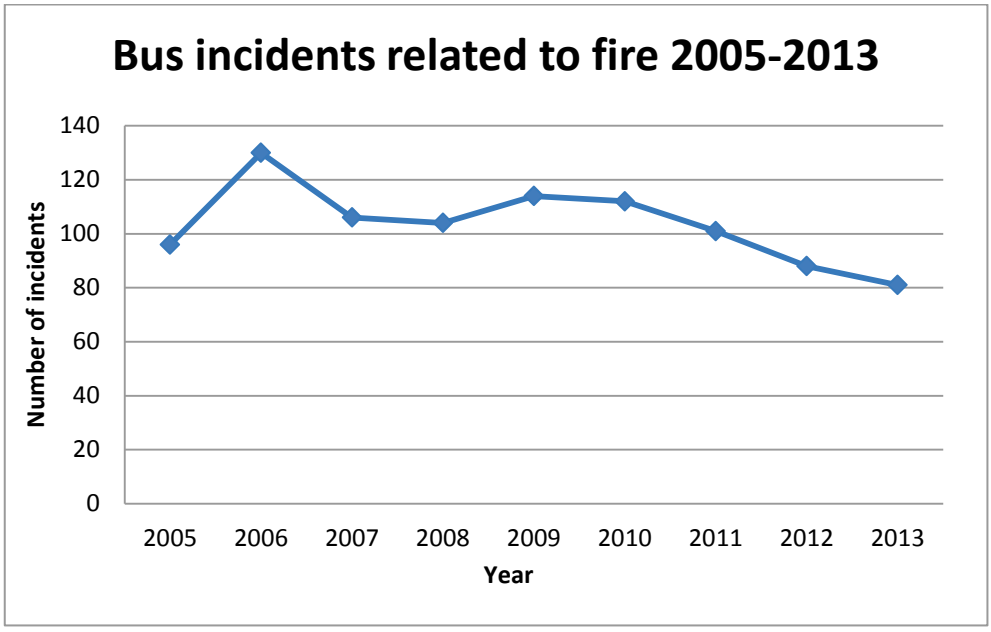

Figure 3 Number of bus incidents related to fire 2005 - 2013.

The average proportion of bus incidents in proportion to the total number of buses in commercial traffic (see Figure 1) during each year between 2005 and 2013 is 0.76 %.

3.2 Initial nature of the incident

Initial nature of bus incidents related to fire are divided into two categories, fire and smoke. Cases in which information regarding initial nature of the incident could not be explicitly read due to insufficient data were placed in the fire category. The two categories were defined as follows:

- **Fire** - Cases in which it was stated that there has been a fire, there still is a fire upon FRS arrival and/or where the data is flawed but where the fire cannot be excluded.

- **Smoke** - Cases in which it was stated that initial nature of incident was smoke and that the incident did not develop to fire, for instance overheated brakes and wheel bearings, smoke from the instrument panel or from oil leaks or coolant.

The distribution of initial nature of incidents between 2005 and 2013 is presented in Figure 4.

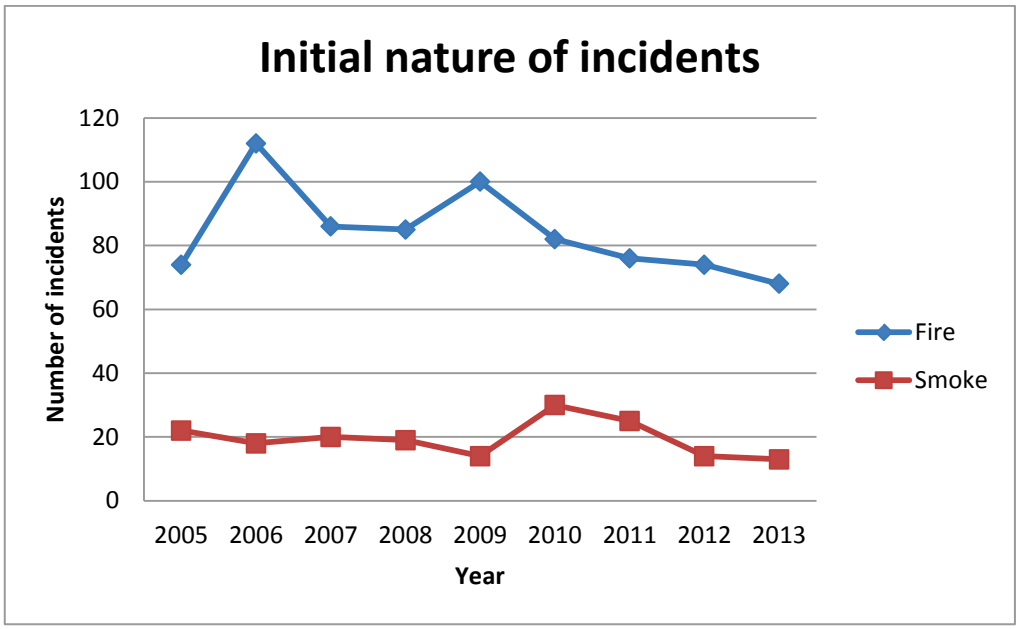

Figure 4 Initial nature of incidents 2005 - 2013.

3.3 Origin area of incident

Investigation of the cause of fire is in many cases not a part of FRS job assignment, i.e. FRS does not conduct fire investigation of the accident after finishing extinguishing operation. Due to the uncertainty regarding the cause of incidents in the data material, only origin of incident was mapped. Origin area was divided into five categories:

- **Engine compartment** - Cases in which the incident has originated in the engine compartment, e.g. by electrical failures or leaking oil igniting on a hot surface within the engine compartment. This category also includes cases where it was stated that the incident originated in a diesel heater / auxiliary heater.
- **Wheel well** – Cases in which the incident originated in the wheel well, for instance due to overheating in wheel bearings, brakes or tires.
- **Passenger compartment** – Cases in which the incident originated in the passenger compartment, including the driver's area.
- **Other** – Cases that do not fit in any of the categories listed above, for instance fire in battery box, motor for windshield wiper, side marker lights etc.
- **Unknown** - Cases in which data is too flawed to define the origin area.

Figure 5 illustrates the development of the number of incidents distributed among the defined origin areas.

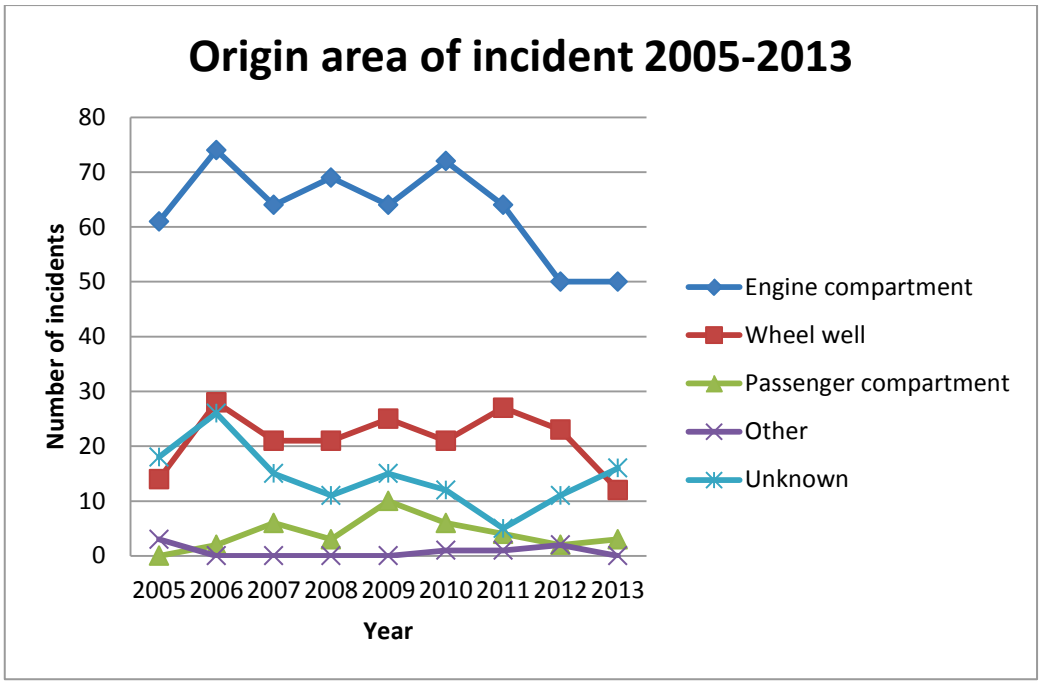

Figure 5 Origin area of incident 2005 - 2013.

3.4 Extent of the incident upon FRS arrival to the accident site

The extent of incident upon FRS arrival has been divided into five different categories. Categories were defined as follows:

- **No fire** - Cases in which there was no fire upon FRS arrival to the accident site. In some cases, there was still smoke but the assessment was made that there was no risk of re-ignition. Hence, FRS did not perform any action.
- **Smoke** - Cases in which there was no fire upon FRS arrival to the accident site. However, in these cases the assessment was made that there was a risk of re-ignition and thus action is performed by cooling the affected area.
- **Limited fire** – Cases in which the fire did not spread beyond its initial origin area and was extinguished by FRS upon arrival.
- **Severe fire** - Cases in which the fire had spread beyond its initial origin area upon FRS arrival. The fire was extinguished by FRS upon arrival and did not lead to flashover.
- **Flashover** - Cases which resulted in flashover prior to FRS arrival.

The results are presented in Figure 6.

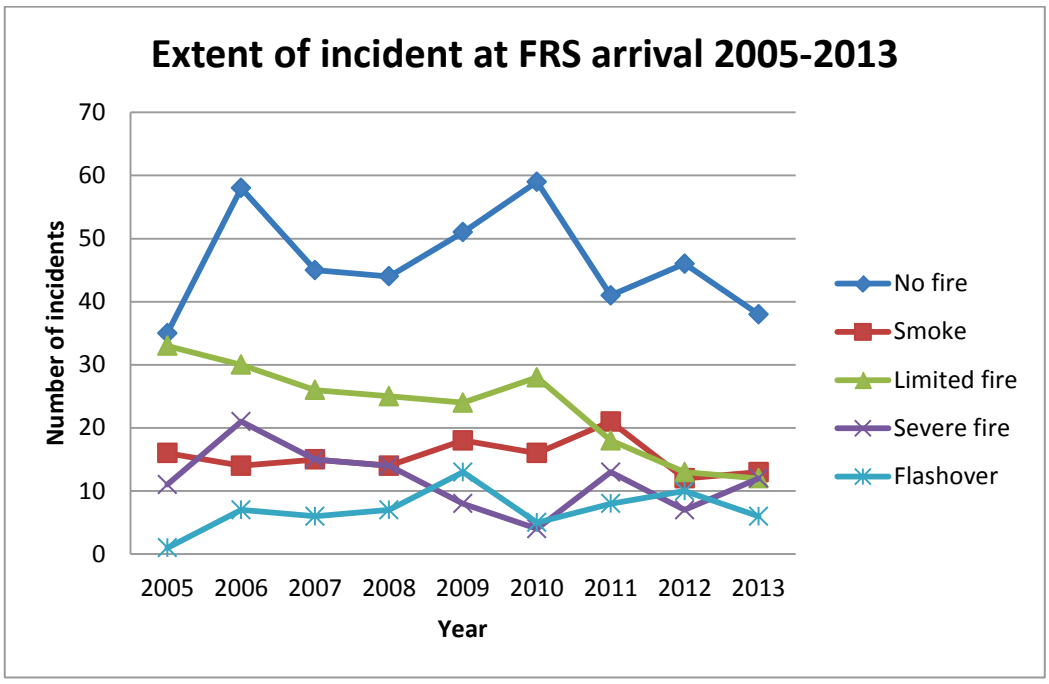

Figure 6 Extent of incident upon FRS arrival 2005 - 2013.

3.5 Extinguishing efforts

This section presents extinguishing efforts performed by FRS as well as extinguishing efforts carried out prior to FRS arrival at the accident site.

3.5.1 FRS extinguishing efforts

Figure 7 shows the number and the proportion of call outs in which FRS conducts an action.

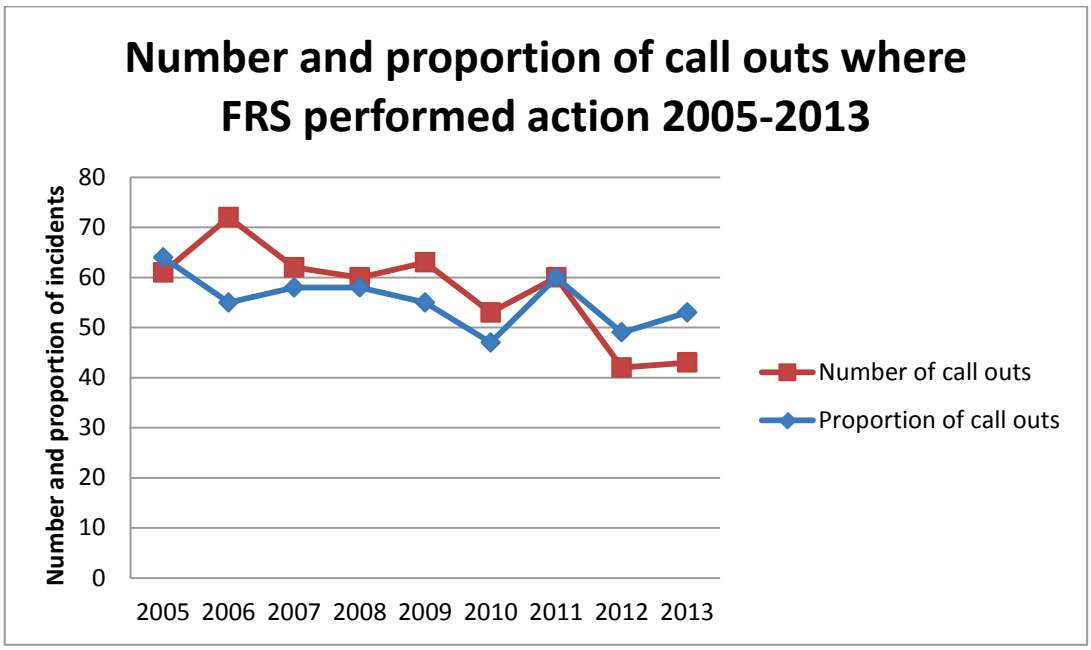

Figure 7 **Proportion and number of call outs in which FRS performed action 2005 - 2013.**

3.5.1.1 Type of action

The type of action was defined in two categories:

- **Extinguishing** – Cases in which there was an ongoing fire upon FRS arrival to the accident site and extinguishing action was performed.
- **Cooling** – Cases in which there was no fire upon the FRS arrival to the accident site. However, an assessment was made that there was a risk of re-ignition and cooling of the affected area was thus performed.

Figure 8 shows the distribution of the type of action FRS performed at arrival to accident site; the figure summarizes only the cases in which action was necessary.

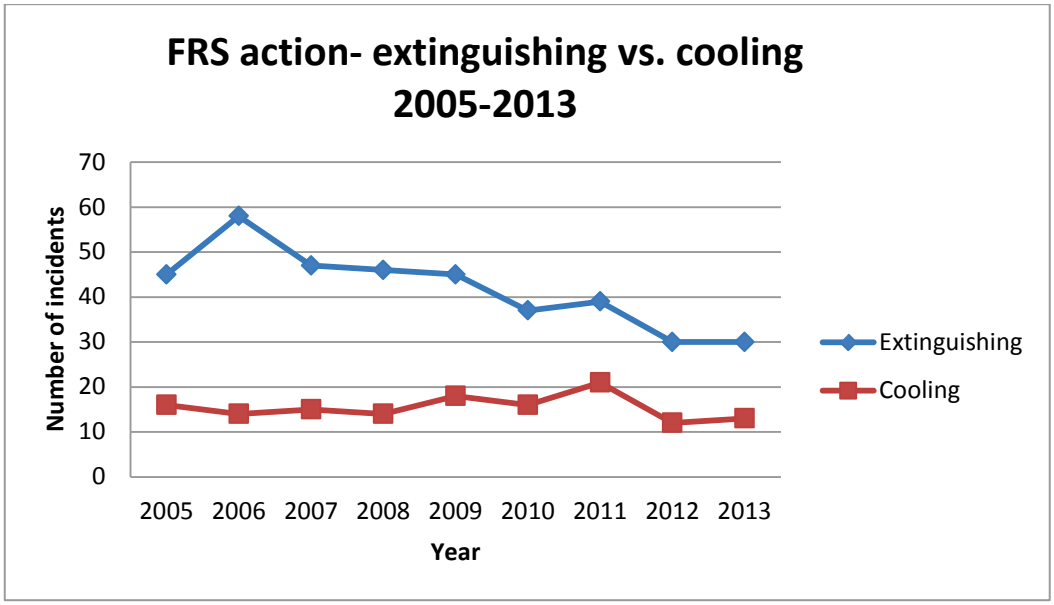

Figure 8 Type of action FRS conducted upon arrival to accident site 2005 - 2013.

3.5.2 Initial extinguishing efforts

This section presents extinguishing efforts executed prior to FRS arrival on the accident site. Two categories of performers for the initial extinguishing effort were defined:

- **Bus driver or staff -** Cases in which it was expressly stated in the incident report that bus driver or staff carried out a first extinguishing effort. The staff includes people who work on the bus or in the bus garage.
- **Other -** This category includes all other cases where it was stated that an initial extinguishing effort is completed. For instance automatic extinguishing system, passengers, passers-by as well as cases where it was stated that the initial effort was made but not stated by whom.

The results show that bus drivers and staff were registered to conduct initial effort in average of 38 % of the incidents between 2005 and 2013. The data for the category *Other* were to substandard to be able to draw any conclusions. The effect of initial extinguishing effort was defined in four categories:

- **Extinguishes fire** – Cases in which the fire was extinguished prior to FRS arrival.
- **Suppresses fire** – Cases in which attempts were made to extinguish the fire, but where the fire is still ongoing at FRS arrival.
- **Cooling –** Cases in which the incident did not develop into a fire, but only smoke and overheating. The initial effort was to cool down the affected area.
- **No effect** – Cases in which the incident developed to flashover despite initial extinguishing effort.

The average distribution of the bus drivers' performance and efficiency between 2005 and 2013 is presented in Figure 9.

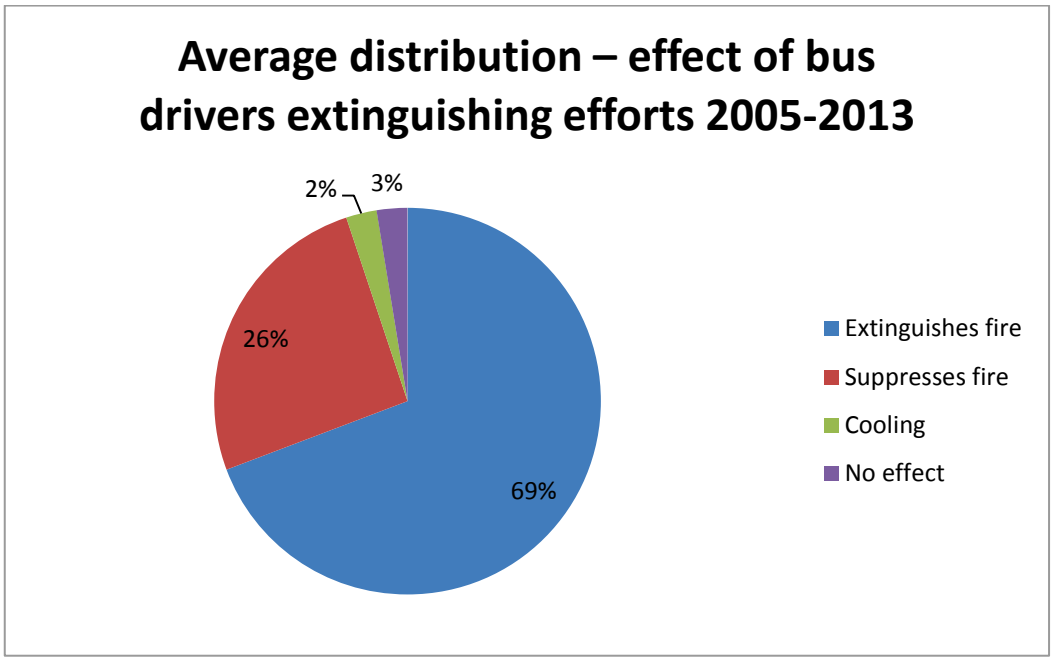

Figure 9 **Average distribution of the effect of the bus drivers extinguishing efforts 2005 - 2013.**

3.6 Engine compartment and wheel well

On average, 86 % of the incidents that originated in the engine compartment were fire incidents; and the remaining 14 % were smoke incidents. The distribution of the incidents originated in the wheel well is 62 % fire and 38 % smoke incidents. Within the concept for smoke incident, as defined in Section 3.2, incidents of smoke as initial nature do not develop into a fire. Due to this fact, this section examines only cases in which fire has been the initial nature of the incident.

3.6.1.1 Engine compartment – fire as the initial nature of incident

Figure 10 presents the distribution of the fires extent at FRS arrival on accident site.

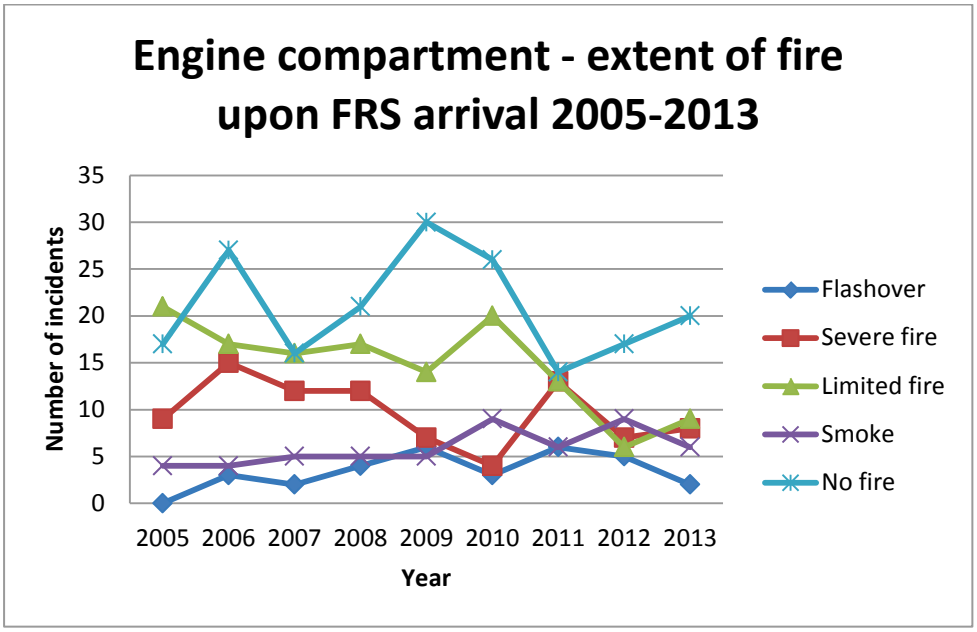

Figure 10 Engine compartment - extent of the incident at FRS arrival 2005 - 2013.

3.6.2.1 Wheel well – fire as the initial nature of incident

Figure 11 presents the distribution of the fires extent at FRS arrival to the accident site.

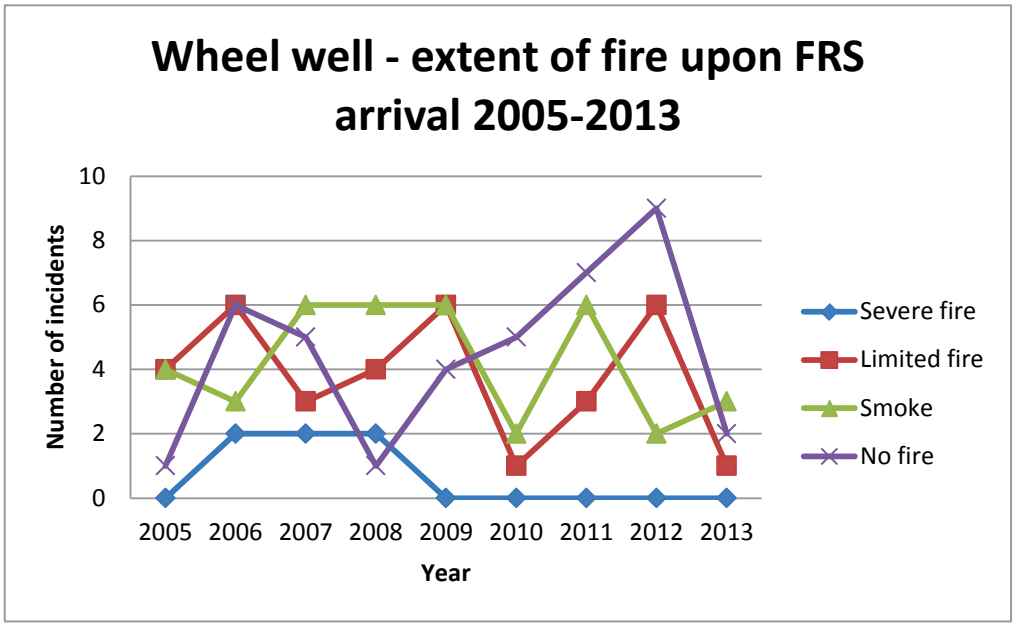

Figure 11 Wheel well - extent of the incident upon FRS arrival 2005 - 2013.

3.8 Response time & total operation times

Response time and total operation time are defined as follows:

- **Response time** – The total time from the moment the alarm is received by the FRS to the time FRS arrived on the accident site.
- **Total operation time** - The total time from the moment the alarm is received by the FRS to the time FRS has completed the operation and is leaving the accident site.

The shortfall of data was 11 % due to this fact that some of the data set contained zero values and outliers. Zero values are cases where no registration in response time or operation time has been recorded in the incident report. Outliers are the values that were disproportionate to the effort that FRS carried out. Consequently, these values were considered as incorrect and thus removed from the assembly. Figure 12 presents the average response times for FRS.

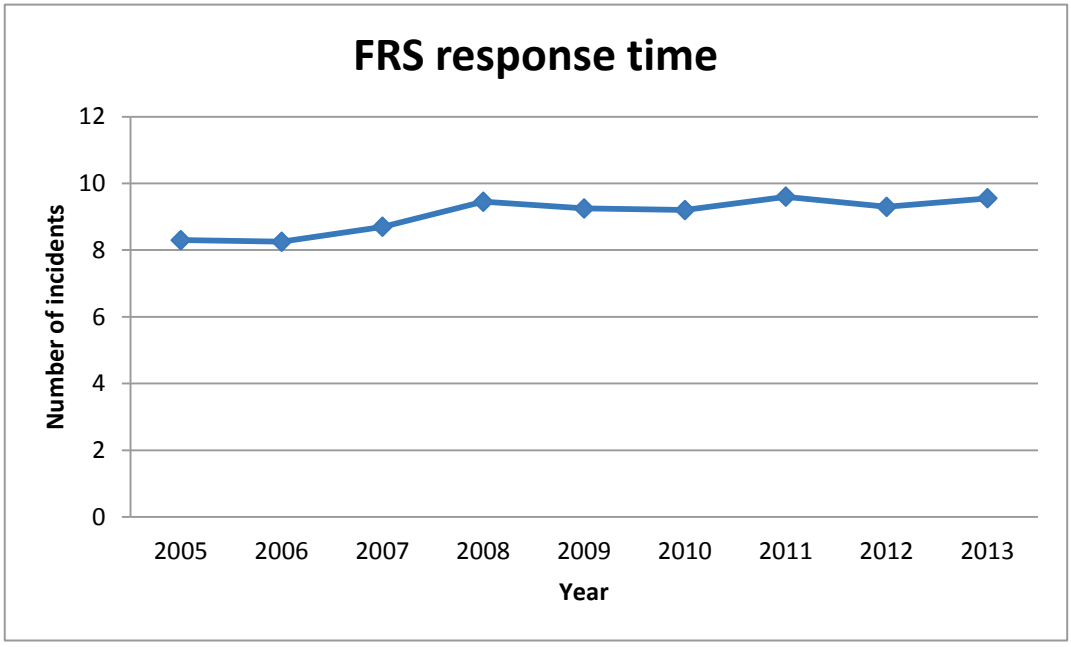

Figure 12 FRS response time 2005 - 2013.

Figure 12 shows operation times when FRS performed and did not perform action.

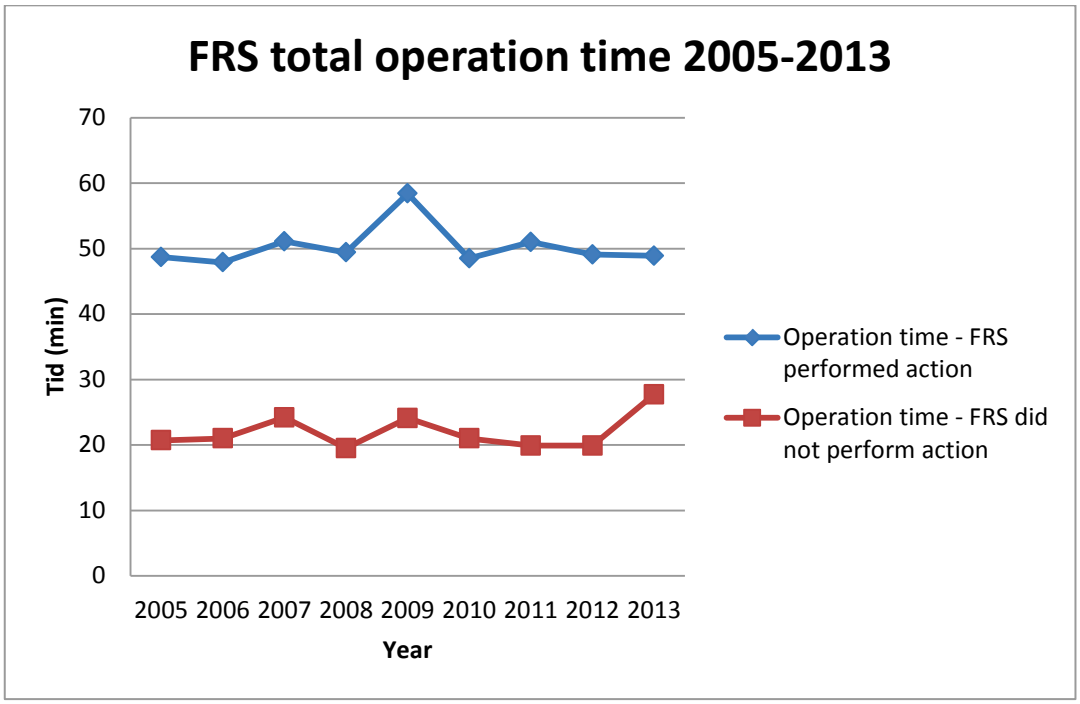

Figure 13 **FRS total operation time - FRS performed action vs FRS did not perform action 2005 - 2013.**

4 Discussion

Three of the created parameters corresponded exactly to the original variables in the template for incident report, namely *FRS performs action*, *Response time* and *Operating time*. These data were thus very easy to obtain from the incident reports. The other parameters had no exact equivalent variable in the incident report template. Extraction of data for these parameters was therefore depending on the level of detail in the description under variable *Accident sequence* in the incident report.

Although *Cause of fire* variable is a part in the incident report template, investigation of fire cause is rarely included in FRS job description/assignment. Cause of fire is therefore often not registered at all or very unspecifically defined in the incident report.
The three difficult parameters to interpret were *Initial nature of the incident*, *Extent of the incident at FRS arrival* and *Initial extinguishing effort*. As mentioned earlier, the problem lies in fact that the incident reports in some cases are not sufficiently detailed regarding these aspects. This also means that information for some of the parameters could only be obtained in those cases the information was explicitly stated in the data material. As a consequence, there arises a certain loss in the reporting of the results.

In the view of the above reasoning, it is important to point out that the results obtained from this survey cannot be interpreted as an absolute true description of reality. There are some uncertainties and hence room for certain degree of interpretations in processing of the data. Nevertheless, precisely for this reason, clear definitions were created for the different categories of each parameter. In this way, some uncertainties in the interpretation have been minimized.

1.1 Bus incidents related to fire

The results of this study show that an average of 0.76 % of the buses in the commercial traffic between years 2005 and 2013 have been involved in incidents related to fire. These results are entirely based on incidents reported to FRS. However, it is difficult to assess the number of unreported bus incidents related to fire. One way of collecting this data would be to implement a survey based on bus companies' statistics and incident reports. Although the value of 0.76 % can give a general idea of the extent of the problem, it does not represent a detailed picture of reality from which conclusions with real significance can be drawn. Incident reports do not reveal details about the vehicles involved in the accident. The data does not reveal the model, manufacturer, model, age, number of days in operation, distance travelled, fuel type, etc. This could, however, be addressed with an alteration in the template for incident report. A proposal is to link the incident report to the Transportation Board's database of vehicle information. All the relevant information on the particular vehicle could thus be obtained and registered in the incident report simply by registering the license plate number of the vehicle. This information could then be used in a more specific way to draw conclusions regarding for example type of buses that are most frequently affected. In addition, more significant correlations could perhaps than be made by studying the buses age or mileage in relation to buses involved in the incidents.

1.2 Initial nature of incident

The point of distinguishing between fire and smoke development in the initial mode was to get a more nuanced picture of the actual incidents. However, the cause behind smoke incidents is of interest since these cases often are of the same basic nature as the fire incidents and are thus potential fire hazards.

It should be emphasized that smoke incidents in some cases may have been limited to that due to activation of fire suppression system. However, this information could not be extracted from the data material and is therefore only noted as a possibility and not stated as a fact.

1.3 Origin area of incident

It is of great interest to know the cause behind each incident as specific as possible. In order to identify the causes of fires in a more detailed way, it requires that a fire investigation is carried out as a follow-up to the incident. Investigations are more frequently done in cases where the incident is reported to the insurance company. It may also be made by the bus companies and bus manufacturers, as it is in their interest to prevent future incidents. In other words, a more detailed and specific survey on fire causes can be done through an study based on investigation reports from these two sources. Another approach could be to conduct a study similar to that conducted in Finland 2010-2012 [5], where each bus fire was followed up by a fire investigation to extract relevant information regarding the accident.

1.4 Extinguishing efforts

Since information regarding initial extinguishing efforts is not an independent variable in the incident report template, this information could only be obtained with certainty in cases in which it was explicitly stated in the description of the course of events. Consequently, the results obtained from the data material are substandard regarding the initial extinguishing efforts. This applies in particular to the number of registered cases that the automatic extinguishing system has been activated. In only one case over the entire nine year period, it is explicitly stated that the fire has been extinguished with the interaction between automatic suppression system and bus driver. The engine compartment was origin area of incident in total of 567 cases between 2005 and 2013. Only in 30 of these cases, which correspond for 5 %, it was explicitly stated that the automatic suppression system has been activated. Since 2004, there is a requirement from insurance companies in Sweden that all insured buses have installed automatic suppression systems. The number of buses with automatic suppression system in the engine compartment of the contracting bus services has increased from 51 % (4522 of a total of 8831 buses) in 2009 to 86 % (8497 of a total of 9842 buses) in 2013 [1] [6]. Hence, it is reasonable to assume that the automatic suppression system has been activated considerably more times than only 30 of the incidents the results in this survey presents.

One probable reason why the activation of the automatic suppression system is not registered in the incident reports is that the firefighters conducting the extinguishing action do not actively investigate the system after completed mission. However, initial efforts conducted by the bus drivers get registered to a much greater extent. This is likely due to the fact that bus drivers are the ones that most frequently meet up the FRS upon their arrival on the accident site and brief them about the course of event; hence their own efforts.

The bus driver extinguished the fire in 26 % of the cases, eliminating the risk of fire spread. The bus driver's initial action can save both lives and property. It is therefore of great importance that the bus driver's education and training includes fire safety issues. This means theoretical knowledge, but also continuous practical exercise in order to handle a fire extinguisher in a convenient and efficient manner. According to Swedish

Road Administrations regulations on the initial qualification and continuing training of drivers carrying goods or passengers [7], a professional driver who carries passengers has to know how to apply firefighting measures and evacuate the passengers in case of fire. However, there is not a clear definition of what applying measures in case of fire means. Nor is there a clear guideline or standard for how education and training should be conducted in order to achieve the desired skills. In other words, this means that the quality and extent of education may vary between educators.

5 Conclusions

The following conclusions can be drawn from the results obtained regarding bus incidents frequency, origin area, fires extent and extinguishing efforts:

- Average number of the reported bus incidents related to fire between 2005 and 2013 is 104. Despite the fact that the lowest number of incidents is registered in 2012 and 2013, studying the whole period no definitive conclusion regarding a downward trend can be made. In order to reach such a conclusion, the number of incidents needs to remain at the current level, or perhaps even continue to decline in the coming years. Furthermore, it is reasonable to assume that there are a number of incidents that do not get reported to FRS. This figure is difficult to estimate without further studies.

- Buses involved in incidents related to fire between 2005 and 2013 correspond to a yearly average of 0.76 % of the total bus fleet in commercial traffic. This figure presents a general description of the reality. However, it does not reveal details about the vehicles involved in the accident. To address this problem, the proposal is to link the incident report to the Transportation Board's database of vehicle information. In this way, all the relevant information on the vehicle involved in the incident, such as the manufacturer, model, age, number of days in operation, distance travelled, fuel type, etc., could be obtained and registered in the incident report simply by recording the license plate number of the vehicle. This data could then be used in a more specific way to draw conclusions regarding vehicles involved.

- Engine compartment is with 64 % of the cases by far the most common origin area for fire incidents on buses and wheel well the second leading with 20 % of the cases. The number of fires originated in the engine compartment is considerably lower in 2012 and 2013 relative to the rest of the seven years studied. This correlates to the general pattern regarding the number of bus incidents in general. To more specifically identify the cause of fires requires processing of the data from other sources; such as incident reports from the bus companies, bus manufacturers and insurance companies.

- Flashover occurred in 7% of all recorded incidents between 2005 and 2013. In 49% of registered cases flashover fires originated in the engine compartment, in the remaining 51% of cases the origin area was unknown. The number of flashover fires varies during the studied period and there is no indication if the trend is moving downward or upward.

- FRS conducted action on average in 55% of call outs. The number of incidents which have required extinguishing effort from FRS has been on a slightly downward trend since 2006. However, the total number of action performed by FRS (including extinguishing and cooling) has primarily been low in 2012 and 2013, which also follows the same pattern as the number of incidents in general for the surveyed period.

- Bus drivers have a significant role in the initial extinguishing effort. Bus driver (or staff) extinguished the fire in 26 % of the occurred fire incidents between 2005 and 2013. Nevertheless, improvements can be made in bus drivers' education and training in terms of more solid guidelines and skill requirements regarding fire safety issues. Such an improvement could potentially lead to more bus fires being restricted or eliminated prior to FRS arrival.

- Information in the studied data was too flawed to draw any conclusions regarding the automatic suppression systems significance and effectiveness. However, it can be assumed that the automatic suppression system has deployed considerably more often than only in 30 out of 567 of the incidents that have originated in the engine compartment, as the obtained results shows.

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Appendix A

Collection of tables

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Table 1 **Number and proportion of fire incidents in commercial traffic and excluded records 2005 - 2013.**

Year	Commercial transport	Excluded records	Total
2005	96 (73 %)	35 (27 %)	131
2006	130 (80 %)	32 (20 %)	162
2007	106 (77 %)	31 (23 %)	137
2008	104 (75 %)	35 (25 %)	139
2009	114 (75 %)	39 (25 %)	153
2010	112 (79 %)	29 (21 %)	141
2011	101 (69 %)	46 (31 %)	147
2012	88 (72 %)	35 (28 %)	123
2013	81 (66 %)	41 (34 %)	122
Mean	**104 (74 %)**	**36 (26 %)**	**140**

Table 2 **Bus incidents in relation to buses in commercial traffic 2005 - 2013.**

Year	Bus incidents	Commercial buses
2005	96 (0,72 %)	13 405
2006	130 (1,00 %)	13 500
2007	106 (0,80 %)	13 282
2008	104 (0,75 %)	13 794
2009	114 (0,85 %)	13 351
2010	112 (0,83 %)	13 567
2011	101 (0,74 %)	13 711
2012	88 (0,63 %)	13 860
2013	81 (0,58 %)	13 883
Mean	**104 (0,76 %)**	**13 595**

Table 3 **Initial nature of incident 2005 - 2013.**

Year	Fire	Smoke	Total
2005	74 (75 %)	22 (23 %)	96
2006	112 (83 %)	18 (14 %)	130
2007	86 (80 %)	20 (19 %)	106
2008	85 (81 %)	19 (18 %)	104
2009	100 (88 %)	14 (12 %)	114
2010	82 (73 %)	30 (27 %)	112
2011	76 (75 %)	25 (25 %)	101
2012	74 (82 %)	14 (16 %)	88
2013	68 (78 %)	13 (22 %)	81
Mean	**84 (81 %)**	**20 (19 %)**	**104**

Table 4 Origin area of incident 2005 - 2013.

Year	Engine compartment	Wheel well	Inside bus	Other	Unknown	Total
2005	61 (64 %)	14 (15 %)	0 (0 %)	3 (2 %)	18 (19 %)	96
2006	73 (57 %)	28 (22 %)	2 (1 %)	0 (0 %)	27 (20 %)	130
2007	64 (60 %)	21 (20 %)	6 (6 %)	0 (0 %)	15 (14 %)	106
2008	69 (66 %)	21 (20 %)	3 (3 %)	0 (0 %)	11 (11 %)	104
2009	64 (56 %)	25 (22 %)	10 (9 %)	0 (0 %)	15 (13 %)	114
2010	72 (64 %)	21 (19 %)	6 (5 %)	1 (1 %)	12 (11 %)	112
2011	64 (63 %)	27 (27 %)	4 (4 %)	1 (1 %)	5 (5 %)	101
2012	50 (57 %)	23 (26 %)	2 (2 %)	2 (2 %)	11 (13 %)	88
2013	50 (62 %)	12 (15 %)	3 (3 %)	0 (0 %)	16 (20 %)	81
Mean	**63 (61 %)**	**21 (20 %)**	**4 (4 %)**	**1 (1 %)**	**15 (14 %)**	**104**

Table 5 Extent of incident at FRS arrival 2005 - 2013.

Year	No fire	Smoke	Limited fire	Severe fire	Flashover	Total
2005	35 (36 %)	16 (17 %)	33 (34 %)	11 (12 %)	1 (1 %)	96
2006	58 (45 %)	14 (11 %)	30 (23 %)	21 (16 %)	7 (5 %)	130
2007	44 (41 %)	15 (14 %)	26 (25 %)	15 (14 %)	6 (6 %)	106
2008	44 (42 %)	14 (13 %)	25 (25 %)	14 (13 %)	7 (7 %)	104
2009	51 (45 %)	18 (15 %)	24 (22 %)	8 (7 %)	13 (11 %)	114
2010	59 (53 %)	16 (14 %)	28 (25 %)	4 (4 %)	5 (4 %)	112
2011	41 (41 %)	21 (23 %)	18 (16 %)	13 (13 %)	8 (8 %)	101
2012	46 (52 %)	12 (14 %)	13 (15 %)	7 (8 %)	10 (11 %)	88
2013	38 (47 %)	13 (16 %)	12 (15 %)	12 (15 %)	6 (7 %)	81
Mean	**47 (45 %)**	**15 (14 %)**	**23 (22 %)**	**12 (12 %)**	**7 (7 %)**	**104**

Table 6 Proportion and number of call outs in which FRS performed action 2005 - 2013.

Year	Action	No action	Totalt
2005	61 (64 %)	35 (36 %)	96
2006	72 (55 %)	58 (45 %)	130
2007	62 (58 %)	44 (42 %)	106
2008	60 (58 %)	44 (42 %)	104
2009	63 (55 %)	51 (45 %)	114
2010	53 (47 %)	59 (53 %)	112
2011	60 (59 %)	41 (41 %)	101
2012	42 (48 %)	46 (52 %)	88
2013	43 (53 %)	38 (47 %)	81
Mean	**57 (55 %)**	**47 (45 %)**	**104**

Table 7 Type of action performed by FRS 2005 - 2013.

Year	Extinguishing	Cooling	Total
2005	45 (74 %)	16 (26 %)	61
2006	58 (81 %)	14 (19 %)	72
2007	47 (76 %)	15 (24 %)	62
2008	46 (77 %)	14 (23 %)	60
2009	45 (71 %)	18 (29 %)	63
2010	37 (70 %)	16 (30 %)	53
2011	39 (65 %)	21 (35 %)	60
2012	30 (71 %)	12 (29 %)	42
2013	30 (70 %)	13 (30 %)	43
Mean	**42 (73 %)**	**15 (27 %)**	**57**

Table 8 Initial extinguishing effort prior to FRS arrival 2005 - 2013.

Year	Bus driver or staff	Other	No initial effort	Total
2005	23 (24 %)	11 (11 %)	62 (65 %)	96
2006	51 (39 %)	12 (9 %)	67 (52 %)	130
2007	43 (41 %)	9 (8 %)	54 (51 %)	106
2008	41 (39 %)	12 (12 %)	51 (49 %)	104
2009	55 (48 %)	12 (11 %)	47 (41 %)	114
2010	37 (33 %)	20 (18 %)	55 (49 %)	112
2011	43 (43 %)	12 (12 %)	46 (45 %)	101
2012	29 (33 %)	14 (16 %)	45 (51 %)	88
2013	30 (37 %)	14 (17 %)	37 (46 %)	81
Mean	**39 (38 %)**	**13 (12 %)**	**52 (50 %)**	**104**

Table 9 Engine compartment - initial nature of incident 2005 - 2013.

Year	Fire	Smoke	Total
2005	51 (84 %)	10 (16 %)	61
2006	66 (90 %)	7 (10 %)	73
2007	51 (80 %)	13 (20 %)	64
2008	59 (86 %)	10 (14 %)	69
2009	62 (98 %)	2 (3 %)	64
2010	62 (86 %)	10 (14 %)	72
2011	52 (81 %)	12 (19 %)	64
2012	44 (88 %)	6 (12 %)	50
2013	45 (90 %)	5 (10 %)	50
Mean	**54 (86 %)**	**8 (14 %)**	**62**

Table 10 Engine compartment - extent of the incident at FRS arrival 2005 - 2013.

Year	No fire	Smoke	Limited fire	Severe fire	Flashover	Total
2005	17 (31 %)	4 (8 %)	21 (43 %)	9 (18 %)	0 (0 %)	51
2006	27 (41 %)	4 (6 %)	17 (26 %)	15 (23 %)	3 (4 %)	66
2007	16 (30 %)	5 (10 %)	16 (32 %)	12 (24 %)	2 (4 %)	51
2008	21 (36 %)	5 (8 %)	17 (29 %)	12 (20 %)	4 (7 %)	59
2009	30 (48 %)	5 (8 %)	14 (23 %)	7 (11 %)	6 (10 %)	62
2010	26 (42 %)	9 (15 %)	20 (32 %)	4 (6 %)	3 (5 %)	62
2011	14 (26 %)	6 (12 %)	13 (25 %)	13 (25 %)	6 (12 %)	52
2012	17 (39 %)	9 (20 %)	6 (14 %)	7 (16 %)	5 (11 %)	44
2013	20 (44 %)	6 (13 %)	9 (20 %)	8 (18 %)	2 (5 %)	45
Mean	**21 (38 %)**	**6 (11 %)**	**15 (27 %)**	**10 (18 %)**	**3 (6 %)**	**62**

Table 11 Wheel well - initial nature of incident 2005 - 2013.

Year	Fire	Smoke	Total
2005	9 (64 %)	5 (36 %)	14
2006	17 (61 %)	11 (39 %)	28
2007	16 (76 %)	5 (24 %)	21
2008	13 (62 %)	8 (38 %)	22
2009	16 (64 %)	9 (36 %)	25
2010	8 (38 %)	13 (62 %)	21
2011	16 (59 %)	11 (41 %)	27
2012	17 (74 %)	6 (26 %)	23
2013	6 (50 %)	6 (50 %)	12
Mean	**13 (62 %)**	**8 (38 %)**	**21**

Table 12 Wheel well - extent of incident at FRS arrival 2005 - 2013.

Year	No fire	Smoke	Limited fire	Severe fire	Flashover	Total
2005	1 (12 %)	4 (44 %)	4 (44 %)	0 (0 %)	0 (0 %)	9
2006	6 (35 %)	3 (18 %)	6 (35 %)	2 (12 %)	0 (0 %)	17
2007	5 (31 %)	6 (37 %)	3 (19 %)	2 (13 %)	0 (0 %)	16
2008	1 (8 %)	6 (46 %)	4 (31 %)	2 (15 %)	0 (0 %)	13
2009	4 (25 %)	6 (37 %)	6 (37 %)	0 (0 %)	0 (0 %)	16
2010	5 (62 %)	2 (25 %)	1 (13 %)	0 (0 %)	0 (0 %)	8
2011	7 (44 %)	6 (37 %)	3 (19 %)	0 (0 %)	0 (0 %)	16
2012	9 (53 %)	2 (12 %)	6 (35 %)	0 (0 %)	0 (0 %)	17
2013	2 (33 %)	3 (50 %)	1 (17 %)	0 (0 %)	0 (0 %)	6
Mean	**4 (31 %)**	**4 (31 %)**	**4 (31 %)**	**1 (7 %)**	**0 (0 %)**	**13**

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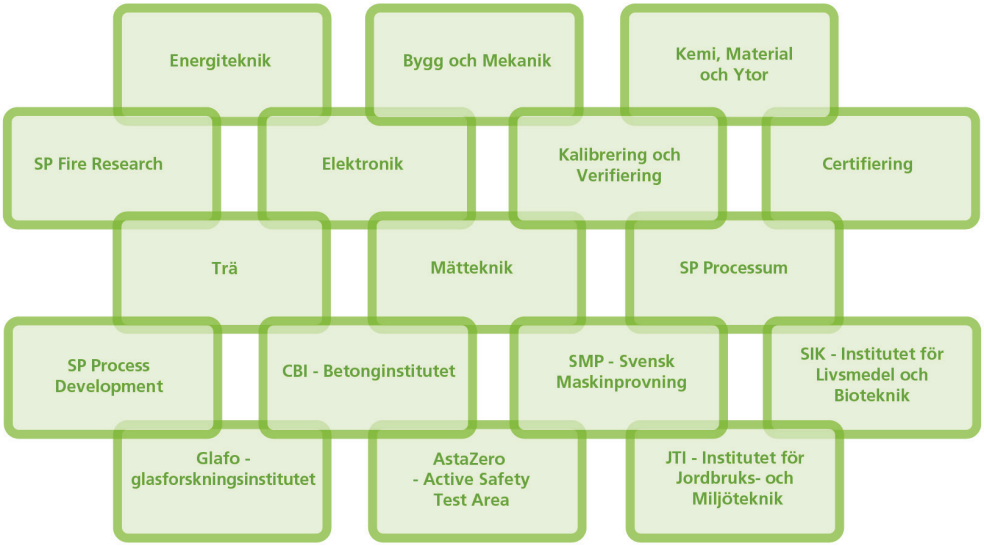

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