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Abstract
Almost 20 years ago, MSB's representatives published general advice and comments on fire protection at camping facilities (SRVFS2004:12). However, this is considered general advice and is not technically mandatory. This advice is linked to 2 kap. 2 § of the Act (2003:778) on protection against accidents, which in this case points out an obligation for owners and users of camping facilities to maintain fire protection to a reasonable extent.

Within this document there contains advice on what distances are needed between camping units to reduce the risk of fire spreading between them. However, there is no deeper background to the prescribed distance requirement given (in general 4 metres). Based on an assessment it appears that the distances between tents and units have not changed since previous guidelines the background knowledge of how these requirements were developed is lost. The requirements have their basis in a notice sheet from the National Rescue Service (1984:5 Fire protection at campsites and the like) but where the distance requirements in that document have their basis is, however, unknown. Furthermore, camping units, like other things in society, have developed significantly over recent time. The development, for example through the choice of materials and more, may have changed the progress of fires in caravans and mobile homes and thus also the risk of spread between them. Thus, the purpose of this project is to make a review of these guidelines, investigate what other countries prescribe, what is written in the scientific literature on this topic, and investigate how materials used in these objects have changed to gain an understanding on whether the given requirement is still considered sufficient or if it needs to be reviewed and revised.

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Table of Contents

1. Background

Almost 20 years ago, MSB's representatives published general advice and comments on fire protection at camping facilities (SRVFS2004:12). However, this is considered general advice and is not technically mandatory. This advice is linked to 2 kap. 2 § of the Act (2003:778) on protection against accidents, which in this case points out an obligation for owners and users of camping facilities to maintain fire protection to a reasonable extent.

Within this document there contains advice on what distances are needed between camping units to reduce the risk of fire spreading between them. However, there is no deeper background to the prescribed distance requirement given (in general 4 metres). Based on an assessment it appears that the distances between tents and units have not changed since previous guidelines the background knowledge of how these requirements were developed is lost. The requirements have their basis in a notice sheet from the National Rescue Service (1984:5 Fire protection at campsites and the like) but where the distance requirements in that document have their basis is, however, unknown. Furthermore, camping units, like other things in society, have developed significantly over recent time. The development, for example through the choice of materials and more, may have changed the progress of fires in caravans and mobile homes and thus also the risk of spread between them. Thus, the purpose of this project is to make a review of these guidelines, investigate what other countries prescribe, what is written in the scientific literature on this topic, and investigate how materials used in these objects have changed to gain an understanding on whether the given requirement is still considered sufficient or if it needs to be reviewed and revised.

2. Methodology

As this is a "desktop study" two main methods of retrieving information relevant to the project are used. For searching the scientific literature two of the largest scientific literature databases: Scopus and Web of Science, were chosen for the data sourcing, which cover journals and articles from major publishers, including the fire science community. Google Scholar and Google search engine are used to supplement and locate the full text of journal papers and technical reports or white papers that were not published on journal platforms. A method based on the PRISMA-ScR method [1] was employed within this project to map and filter the scientific literature, the process of which is outlined below in section 3 using four filtering steps.

For the section 4 – on mapping the regulations from around the world, a similar search method to above was also employed, though largely through the use of search engines such as google. However due to the nature of regulations, being in the language of the country they apply to, and this being hard to search without knowledge of the mother tongue from the given country, another resource was employed, namely the "network of the fire science community". The author reached out to many contacts around the world, and asked them if they could find any information on this topic in the country they were from or resided in. This method was highly effective, and the authors would like to thank all those who helped in this task from around the world.

Section 5 provides brief overview of the materials used in caravan construction and how they have changed over the years. Section 6 briefly highlights the potential risks associated with the usage of li-ion batteries in caravans.

3. Mapping of Scientific Literature

Step 1: Compilation of Keywords

Three sets of keyword groups are used in the initial stages of the literature review, the first set uses the most identifiably relevant keywords, e.g. "fire separation distances in camping sites", "fire separation between caravans" based on the project title and purpose.

The second keyword set then extends the search by using broader search terms related to the project topic such as; "fire spread between temporary structures", "fire safety in camp sites", "caravan fire safety"

The third keyword set constitutes the broadest keyword search using words such as; "fire separation in buildings", "fire spread between structures", "flame spread between cars"

Step 2: Keyword search

Table 1 provides a summary of keyword searches used in searching for relevant papers.

Note: the use of "AND" means the word before and after must both be in the search results. Use of the word "OR" means either one word or the other word can be in the document.

Table 1 - keywords used in search and resultant number of documents found

Keywords used	Search criteria	Document Results	Secondary document results

fire AND separation AND caravans	Article title, Abstract, Keywords	0	0
fire AND spread AND caravans	Article title, Abstract, Keywords	2	0
fire AND caravans	Article title, Abstract, Keywords	24	8
fire AND caravans OR tents OR mobile AND home OR campervan		287	33
fire AND spread AND caravan OR tent OR mobile AND home OR campervan		8	2
fire AND safety AND distances AND caravan OR tent OR mobile AND home OR campervan		2	0
fire AND safety AND distances AND camping		1	0
fire AND spread AND camping		3	0
fire AND safety AND camping		13	1
fire AND spread AND camp AND site		4	1
2nd search			
fire AND separation AND between AND temporary AND structures		1	0
fire AND separation AND between AND tents		0	1*
fire OR flame AND spread AND between AND tents		14	0
fire AND spread AND camps		24	
flame AND spread AND camps		0	0
3rd search			
fire OR flame AND spread AND between AND cars		152	21

fire AND separation AND between AND cars		20	0
fire OR flame AND spread AND between AND vehicles		397	23
fire OR flame AND spread AND between AND structures		1968	66
fire OR flame AND spread AND informal AND settlements		40	18

Found document results based on the keyword searches were downloaded as reference lists and then collated in excel, this resulted in a total of approximately 3200 article references. The "remove duplicates" function in excel was then used to remove all duplicate results within the collated list, reducing the total list to approximately 2500 articles.

Step 3 – Title screening

Title screening acts as the next filter stage of this literature review process, as many of the collected articles are not relevant for this project. Title screening involves scanning the title of each article collected in the stage 2 refinement to review its relevancy to the current project, any titles that are deemed not relevant are then removed for the list. Using this method, the population of articles was reduced to 156.

Step 4 – Abstract screening, Stage 5 – Article review.

In this stage, abstracts of the remaining articles are reviewed and the most relevant are highlighted and the full article is then reviewed in stage 5. Relevance of the articles to this project can be categorised into 3 main subject areas:

1. Articles that address the topic of fire safety distances and fire spread in caravan/camping sites directly.
    - These are the most important and relevant articles; however, they were very limited in number.
2. Articles that address fire safety distances and fire spread in objects that are not directly caravan/camping site related but look at objects/scenarios/cases that are similar.
    - These can be used to supplement the limited number of articles from point 1. Although not exactly following the project topic, they may show similar behaviours, and thus can be used to increase the amount of available data.
3. Articles that investigate fire behaviour of similar objects to caravans/camping structures.
    - These can be used to look at what similar fuel types (e.g. cars/trucks) give in terms of fire outputs, e.g. Heat Release Rates (HRR) and heat fluxes (HF). This is type of data is required for safety/separation distance calculations and can be used to compare to and extend the limited data we could obtained.

A full list of papers from stage 4/5 is supplied in the appendix, and a sample of the most relevant information within these 3 categories from the collected articles is outlined below:

CATEGORY 1

Fire Spread between Caravans [2] is perhaps the most relevant of the found scientific literature. In this research, Shipp investigated heat fluxed coming from two types of caravans (standard moveable and more permanent mobile home), along with critical heats fluxes of common materials found in these objects. The author then developed a method using the experimental results and modelling methods to determine critical safe distances (to reduce the risks of fire spread) between these types of objects. Conclusions resulted in a list of recommendations. Most importantly here:

- fire conditions 10 minutes after ignition when irradiances were at a maximum.
- spacing recommendation were 3.5m to 6m depending on the object type and the material.
- Critical heat fluxes used to find these distance recommendations were 12.6 and $17kW/m^2$.

Additionally, this work, performed by the Building Research Establishment (BRE) in the UK, had a direct impact on the regulations on separation distances within the UK.

In "An analysis of factors influencing structure loss resulting from the 2018 Camp Fire" [3] it was stated that mobile homes were much more likely to be damaged than standard housing. This suggests that separation distances should consider the standard required spacing between "standard" housing as a lower limit.

In "Analysis of Fire Hazard in Campsite Areas" [4] it is stated that "*during several visits to campsites, numerous situations of higher fire risk due to camping activities were identified.* ***Insufficient distance between combustible accessories like tents****, unmannerly car parking, use of fire wood to cook, use of gas to light and to cook, poor maintenance of accessories, fire suppressant equipment not properly located, and lack of training of campers and sometimes of the site staff in fire safety and prevention procedures are among the main issues to be addressed in campsites in order to reduce the fire risk*." However, no specificities on separation distances are given.

Appendix 1 also provides links to various videos of caravan fires, these can be useful to view and look at the fire progression. For example, in many of these it can be observed that the windows and roof hatched as the first places which lose integrity and let the fire escape from within the caravan. This is due to the majority of these opening being made of plastic which melts and then opens up. This observation would lead to fire spread being most likely to occur from these positions.

CATEGORY 2

[5], [6], [7], [8], [9], [10], [11] are examples of research that has been performed, looking into fire spread mechanisms and critical separation distances between other types of buildings and structures. In particular is the work done through the IRIS-Fire project (Improving the Resilience of Informal Settlements) a Global Challenges Research Fund (GCRF) project (EPSRC Grant No. EP/P029582/1).

A large number of articles (most relevant cited here) within the IRIS-fire project have been investigating, thorough different methods (modelling, large and small scale experimentation, mapping etc) how fires spread through informal settlements, which may be considered similar to temporary sites like caravan parks or camping areas.

Most interesting are the large scale experiments [6], [11] performed on a mock sets of "dwellings" while measuring spread rates between them, ranging between 4-8mins in experimental set, while with winds assisting (15-25km/h), and small distances between dwellings, (1-2m) it was shown that within 5mins a whole set of 20 mock-dwelling could be entirely destroyed.

The last example reference given for this section looked at fire safety distances for a burning minivan [12]. In this article, a minivan was burned and the HRR and heat fluxes from the front and side were measured. HRR peaked at between 3-3.4MW and the measured heat fluxes at 1.2m from the left side and the front, and at 1.85m from the left side of the burning vehicle. Using these measurements, the authors looked at safety distances for both humans and other vehicles. 10kW/m^2 was taken as the critical heat flux via radiation to induce ignition of materials like those used in neighbouring cars, and a distance of 2.1m was suggested as the minimum safe distance based on these experimental results. However, these results were based only on radiative heat fluxes and do not account for additional spread factors such as convective heat flux, burning brands and wind related influences.

CATEGORY 3

In "Burning behavior of minivan passenger cars"[13] tested minvans reach peak heat release values of between 3-4MW ranging in time to peak values of between 15-30mins of ignition. This was similar to the results found in [12].

For other vehicles, such as cars[14] used measured values between 1.5-2MW as peak values, however given the age of the paper, this may be considered on the lower side of what might be expected today with the increased use of plastics within newer car designs. [15] provide an extensive review of 44 full scale car fire tests compiled with Polish and British passenger car fire statistics from the last 8 years for the purposes of choosing a design fire relevant for assessing risks in a carpark scenario. In this they suggest using design fire peakHRRs between 2-6MW based on time for arrival of fire and rescue services and the given spread in the data used which considers also multiple car involvement. For a single car HRR 1.5-3MW is considered which is in line with other results obtained from the literature.

Given the size and weight of typical caravans, considering both the older styles and newer styles (more details on the differences in materials is provided in section 5) it is reasonable to consider that a given heat release may be within the region of something slightly greater than a typical car fire, thus peak values (depending on the burning behaviour) may be within 2-10MW allowing for differences in material composition and variations in caravan sizes. However, this should be considered only an approximation and testing would be required in order to get a better understanding and approximation of the fire sizes that could be expected.

4. Mapping Legislation

The following section outlines and summaries what legislation and regulations related to fire safety and separation distances for caravans and camping sites were found from around the world. Only information related to distancing is highlighted here, there may also be other fire safety requirements, i.e. requirements for fire extinguishers etc. however these are excluded from this report. The reader may refer to reference documents for full set of fire safety requirements.

Most relevant countries i.e. Scandinavia (are placed first, following this is other European countries and then the USA and other country globally. Diagrams based on the authors understanding of the main requirements within each country are also provided to enhance the readability. Reference to documents and websites where information in this section was obtained are provided in footnotes rather than in the reference list in the end of the report. It should also be noted, that many of the country regulations that were found were not provided in a common language e.g. English, thus the author was required to translate many of these documents. Translation was done with Google translate, and therefore completely correct interpretation of these documents cannot be guaranteed.

The basis for this project was on the discussion of the current Swedish requirements SRVFS 2004:12[1]. The basics from this document are outlined below to facilitate comparison with other countries:

- The distance between two camping units, or between a camping unit and a tent, should be at least four meters.
    - The distance between two tents should be at least three meters. Shorter distances can be used between a maximum of four tents or camping units if the affected camping guests wish it.
- There should be a plan of the camping facility showing any plot and block division as well as baskets, special fire sectioning measures, where extinguishing equipment is located, etc.

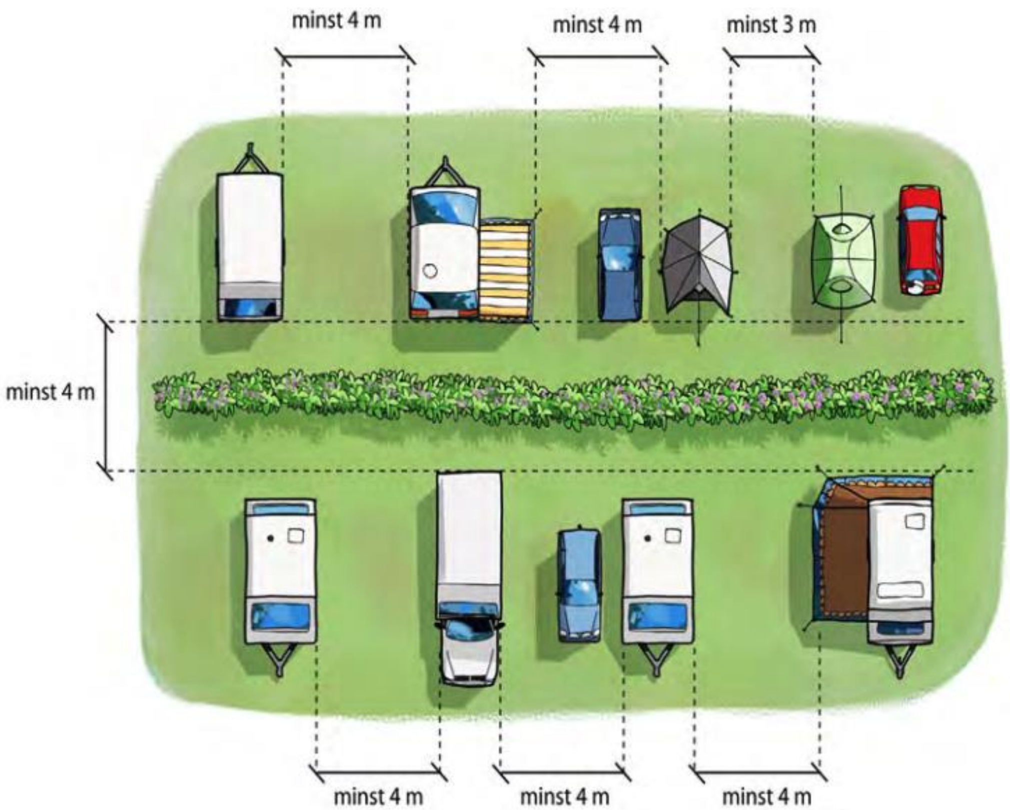

Figure 1 – separation requirements taken from SRVFS 2004:12, diagram taken from MSB document: Brandsäker camping. – tips och råd till dig som campinggäst

4.1. Norway:

Information from Norway is based on updated regulation in Norway from 2017[2]. These were updated based partly on a project undertaken by DSB (in collaboration with RISE Norway).

[1] Statens räddningsverks allmänna råd och kommentarer om brandskydd vid campinganläggningar – SRVFS 2004:12, ISSN 0283-6165

[2] NORSK LOVTIDEND Avd. I Lover og sentrale forskrifter mv. Utgitt i henhold til lov 19. juni 1969 nr. 53. nr. 3448 TEK17. https://lovdata.no/LTI/forskrift/2021-12-09-3448

The following applies to legally established campsites:

- Between camping units, the distance can be reduced to a minimum of 4.0 meters if the total the area of the camping unit does not exceed 75m^2 and the camping unit does not at any point exceed a height of 4.0 meters above the ground. *A camping unit includes a caravan, mobile home, caravan, mobile home etc. with associated tents, awnings, nail tents, terraces, living walls and similar structures.*
    - The distance is measured from extreme point to extreme point of the camping unit.
- The campsite must be divided into parcels with a maximum floor area of 1200m^2. Between the parcels there must be fire escapes of a minimum width of 8.0 metres.

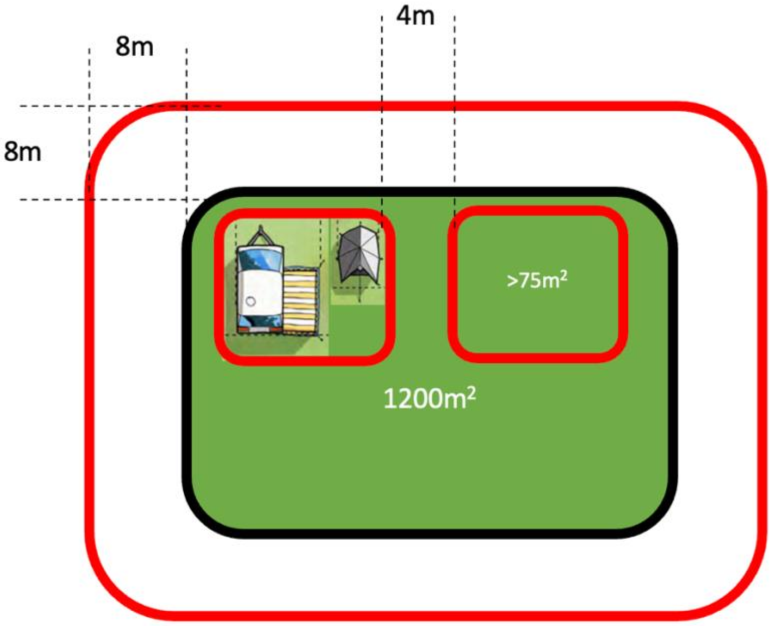

Figure 2 - Authors interpretation of Norwegian requirements

4.2. Denmark:

In Denmark, guidance comes from the building regulations' guidance for chapter 5 – Fire Appendix 11: Pre-accepted solutions for assembly tents, temporary camping areas and temporary outdoor sales areas[3]. Areas are separated between "caravan areas" and "mixed areas" (where both caravan and camping tents may be used). Although requirements for both areas are basically the same, they are spilt here the same as in the original documents for consistency.

[3] Bygningsreglementets vejledning til kapitel 5 – Brand, Bilag 11: Præ-accepterede løsninger for forsamlingstelte, midlertidige campingområder og midlertidige udendørs salgsområder

Caravan areas

Caravan areas are areas where caravans, camplets, motorhomes and similar.

- The caravan areas must be divided into fields of no more than 500 m², and there must be around each field a clear area of at least 5m.

- In a caravan area, a camping unit can consist of, for example, a caravan and a smaller one tent corresponding to an igloo tent or similar of no more than 9m².

    - Any covers, sun sails, awnings or the like that are set up as a permanent part of the camping unit, must be included when the distance requirement is measured.

- In caravan areas, the mutual distance between the camping units must be at least 3m. The mutual distance is calculated from the total camping unit.

    - The distance is measured from the camping wagon box, awnings, smaller tents or the like, while drawbars are not included.

Mixed areas

Mixed areas can consist of camping units made up of caravans and tents.

- Mixed areas must be divided into fields of no more than 500 m², and around each field there must be a clear area of at least 5m.

- In mixed areas, the mutual distance between the camping units must be the minimum 3m.

- In mixed areas, camping units can consist of, for example, a caravan and a smaller one tent, or a larger tent and a smaller tent. The mutual distance is calculated from the total camping unit. A smaller tent is defined as no more than 9m².

- In camping areas, the free areas laid out between the individual fields can be used for evacuating. In tent areas, caravan areas and mixed areas there must never be a length of more than 30 m to the nearest free area.

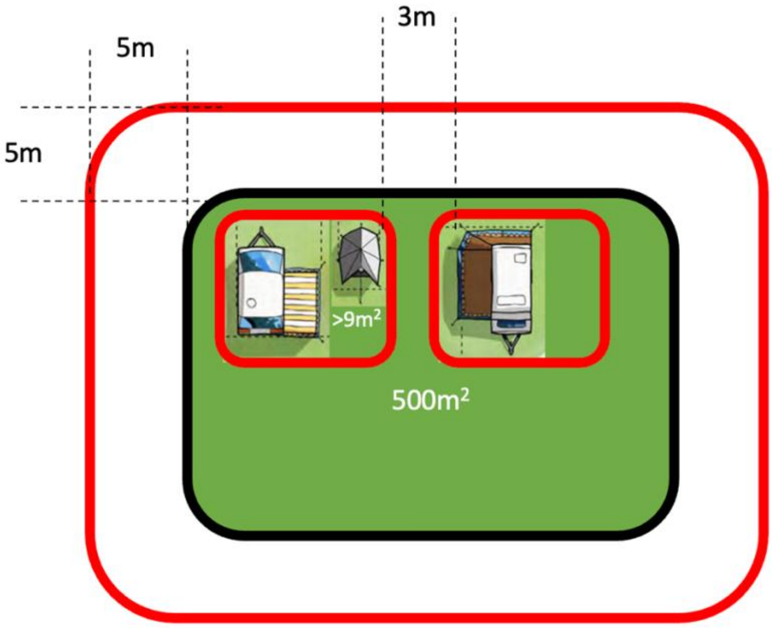

Figure 3 - Authors interpretation of Danish requirements

4.3. Finland:

In Finland, requirements found were issued by the central organisation of the Finnish Rescue Service (SPEK)[4]. Interestingly, there is a note in this document that states "Finland acknowledges the changes in materials over the last year will have made a difference in fire behaviour". Translated quote: "*During the last ten years, the fire loads of motorhomes and tractors have increased considerably. This results in a greater risk of fires spreading than before. Prevailing conditions, such as wind, also affect the progress of the fire. The presented safety distance does not fully ensure that the vehicles next to it are protected from heat damage, for example, when the motorhome burns. According to studies and reports, the almost risk-free safety distance would be around 8 meters.*"

General requirements:

- The safety distance must be at least 4 meters:
  - from another recreational vehicle – from the second front tent
  - from the second front canopy
  - from another wooden laver of the RV site or the related fence
  - from a separate tent
  - from a motorhome used as a towing vehicle
  - from a towing vehicle that is not related to the fire load unit in question.

Other notes:

- The safety distance is measured from the outermost part of the above-mentioned individual objects or the fire load unit formed by them. A typical fire load unit

[4] Suomen Pelastusalan Keskusjärjestö – Leirintäalueen turvallisuusopas. Suomen Pelastusalan Keskusjärjestö SPEK, ISBN 978-951-797-687-9 (pdf) 2. päivitetty painos 2020.

consists of, for example, a caravan, a front tent, a truck and a tow truck, if it is parked 4m closer to the caravan and the front tent.

- The local rescue authority provides practical instructions based on the Rescue Act of the individual campsite.

- A sufficient safety distance from a building or a room built in connection with a recreational vehicle is 8m. Before building the room space, you must find out about the possible permit or notification procedure from building control.

- A sufficient safety distance from the transformer and medium voltage overhead line is 5 meters.

- The size of the RV space is recommended to be 100–120 m2. There is a reason to arrange a few places in the camping area also for recreational vehicles that require more space. It is good to plan the places in such a way that the safety intervals are feasible.

- Caravans and tractors must be easily moved in case of fire. If relocation is not possible, the safety intervals must be extended.

- A protective distance of about 8m is sufficient to prevent heat damage.

- The safety distance between tents intended for accommodation is 4m. Tents for 1–2 people of the same party may be closer to each other.

    - These can form blocks of 50–60 tents (about 100 people).
    - The distance between blocks must be at least 8m.

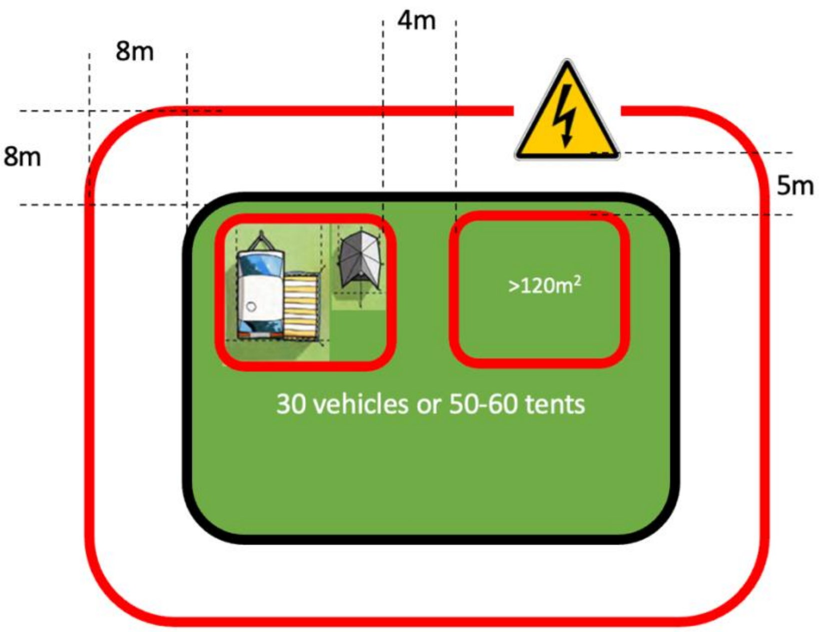

Figure 4 - Authors interpretation of Finnish requirements

4.4. Germany:

In Germany the responsibility for the building codes lies with the 16 federal states. Within the building codes, camping and weekend sites are declared as so called "special buildings", deviating from the general requirements of the building code, special requirements may be imposed for these in individual cases.

For some special buildings there are special ordinances, in this case there are campsite ordinances which are introduced by some of the federal states building authorities. The regulations state that it is only a campsite if there are more than 3 or 4 pitches or tent pitches.

To prevent significant deviations between the states there is a model building code and model ordinances which are published through the conference of building ministers. The federal states can but don't have to follow them. Therefore the regulation of fire safety at campsites including distance between RV's is based on the "Mustercampingplatzverordnung – MCPIVO" (Model Campsite Ordinance) from 1981[5]:

- Campsites and tent sites shall be divided into individual sections by fire lanes at least 5m wide.
- A fire lane is to be arranged after every 10 pitches in a row.

Table 2 - Overview of the regulations on minimum distances and fire protection strips of the respective federal states

Federal State	Max. Sections between Fire Lane	Min. Width of Fire Lane	Min. Distance in between Tents/RVs
Model ordinance	10 in a row	5 m	
Schleswig-Holstein	20 Stands	5 m, tiny houses: 10 m	3 m
Saarland, North Rhine-Westphalia, Saxony-Anhalt	20 Stands or 10 in a row	5 m, tiny houses: 10 m	
Brandenburg	2000 m2	5 m	2 m
Lower Saxony	10 in a row	5 m, tiny houses: 10 m	
Rhineland-Palatinate	20 Stands or 10 in a row		
Baden-Württemberg	20 Stands or 10 in a row	5 m	
Hamburg	10 in a row	5 m	
Mecklenburg-Vorpommern	20 Stands	5 m	

[5] Muster einer Verordnung über Camping- und Zeltplätze (Mustercampingplatzverordnung - MCPIVO) - Entwurf Juni 1981 - Aufgrund des § 111 Abs. 1 Nr. 1 bis 3 MBO wird verordnet.

Bavaria, Berlin, Bremen, Hessen, Saxony, Thuringia	Not regulated by Ordinance

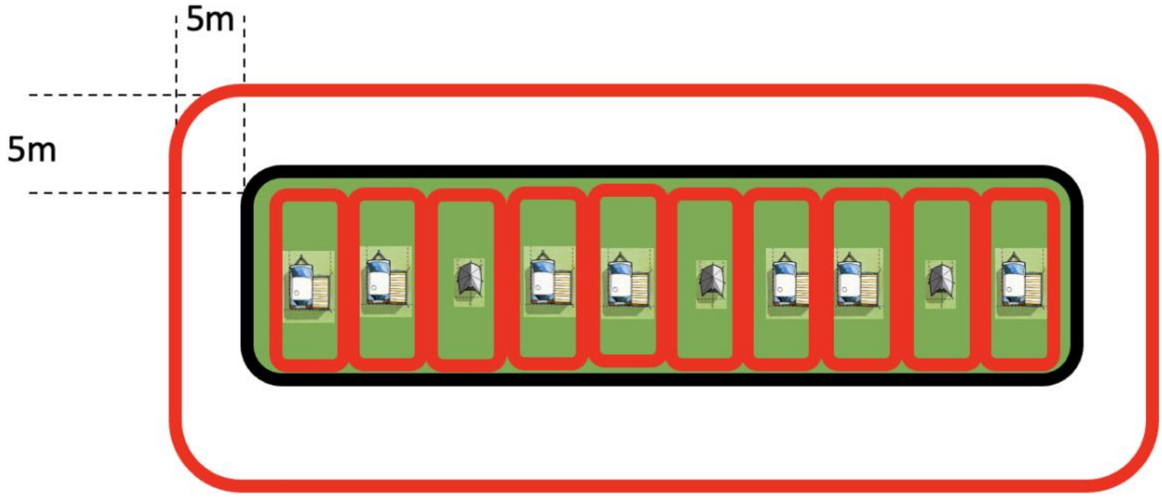

Figure 5 - Authors interpretation of basic "model ordinance" from German requirements

4.5. United Kingdom (UK):

Within the U.K. it seems that the Regulatory Reform (Fire Safety) Order 2005 is the main fire safety legislation in England and Wales and this came into force on 1st October 2006[6]. There is similar legislation for Scotland and Northern Ireland.

Under the Fire Safety Order, and detailed in the relevant DCLG guidance (the DCLG guide for sleeping accommodation). This guide does mention the risk of fire spread and states: "Fire can spread rapidly between caravans and between tents, if they are too close. separation distances between units should be applied, e.g. 6m spacing for park homes. Further guidance on caravan and tent fire precautions can be found in BS 5576, circular 14/89 Model Standards and BRE IP 15/91." This is for "park homes" also known as "trailer park homes" which are more permanent than caravans[6]. This information seems to be based on the BRE report by M. Shipp [2]. Hence:

- the general rule for spacing should be not less than 6m.
- Where awnings are used, the distance between any part of the awning (auxiliary additions to a caravan) and an adjoining caravan should not be less than 3m.

However, some additional nuances are added again, seeming to be based on the BRE report from M. Shipp that consider the materials used in the construction:

- The minimum space between caravans made of aluminium or other materials with similar fire performance properties can be not less than 5m if the Local Authority Site conditions allow it.

[6] FIRE SAFETY REPORT - Motor Caravan Overnight Parking: Report from Fire Decisions Limited.

- For Caravans with a plywood or similar structure we are back to the 6m rule. If a site has a mix of caravans of aluminium and plywood, the separation distance needs to be 6m.

4.5.1. For Scotland[7]

This technical annexe[7] contains benchmarks in respect of holiday camping and caravan sites, against which the existing level of provision can be compared.

Where these benchmarks are not achieved and the results of the risk assessment indicate risk reduction measures are required, consideration should be given to implementing improvements.

- Subject to the variations listed below, the distance between any two tents/caravans should generally be not less than 6 m.

- Variations which allow a reduced distance between units may apply in circumstances where caravan construction is inherently fire-resistant. Under such circumstances, the distance between caravans may be reduced to 5 m or, where the site is laid out in a "chessboard" pattern and the unit construction provides a degree of inherent fire-resistance, the distance may be reduced, subject to risk assessment, from 4.5 m to 3.5 m between the closest corners of the units. Where there is a mix of fire-resistant and non fire-resistant construction, the larger separation distances between caravans will be applicable.

- The distance from any part of the tent/caravan to any site road should be not less than 2 m and not less than 3 m from any site boundary.

- Measurement for the following variations of spacing requirements is taken from the exterior cladding (excluding any tow bar):

    - Porches may protrude 1 m into the 6 m and should be open type construction.
    - Where awnings are used, the distance between any part of the awning and an adjoining caravan should be not less than 3 m. They should not be a type which incorporates sleeping accommodation and they should not face each other or touch.
    - Eaves, drainpipes and bay windows may extend into the 6 m space provided the total distance between the extremities of two adjacent units is not less than 5.25 m.
    - If there are ramps for disabled persons, verandas or stairs extending from the unit, there should be 4.5 m clear space between them and two such items should not face each other in any space. If they are enclosed, they should normally be considered as part of the unit and, as such, should not intrude at all into the 6 m space
    - A garage, shed or covered space should be permitted between units only if of non-combustible construction and enough space is maintained around each unit so not to prejudice means of escape in case of fire. Any windows in such

[7] Fire safety guidance for existing premises with sleeping accommodation, Annex 3 - Holiday Camping and Caravan Sites. ISBN 9781788519656. https://www.gov.scot/publications/practical-fire-safety-guidance-existing-premises-sleeping-accommodation/pages/13/

structures should not face towards the units on either side. Car ports and covered walkways should in no circumstances be allowed within the 6 m space.

Car Parking

- One car only should be permitted to park between adjoining units subject to the entrance to the unit not being obstructed. Plastic/wooden boats should not be kept between units.
- No car parking area providing parking for more than 10 cars should be nearer than 18 m from any part of a unit. If car parks provide parking for 10 cars or fewer then the minimum distance can be reduced to 10 m.

Refuse Disposal

- To avoid the potential for a fire in combustible waste materials, generated by residents and others on the site, regular removal of waste from purpose designed containers should take place.

Fire Hazards

- Grass and other vegetation should be cut at frequent intervals to prevent them becoming a fire hazard.
- Spaces below caravans should not be used for the accumulation of combustible materials storage.
- General guidance on the use and storage of liquefied petroleum gas (LPG) can be found in Chapter 6[7]. Further guidance is available from the supplier or the Liquefied Petroleum Gas Association.
- Open fires should be prohibited on sites.
- The use of barbecue facilities should be strictly controlled and ideally restricted to purpose designed areas within the site remote from units.

4.5.2. Northern Ireland[8]

In Northern Ireland many details are provided for the reader. Criteria common to all sites is given (similar to those in Scotland but are listed below for completeness) but then a table specifying criteria specific to certain types of sites is provided.

Criteria Common to all Sites:

[8] A FIRE SAFETY GUIDE FOR CARAVAN SITE OPERATORS Information on Complying with Fire Safety Law in Northern Ireland document PPG012 – Northern Ireland Fire and Rescue Service. 2018.

- The distance from any part of the caravan to any site road should be not less than 2m and not less than 3m from any site boundary. Clear space of 3m should be maintained between the site boundary and the caravan.

- Where an escape window is provided from a caravan, the means of escape from the window should be maintained to be clear and free from obstruction.

- Porches may protrude 1m into the 6m (or 5m) space and should be of the open type and be no more than 2m wide along the unit.

- The distance between any part of an awning and an adjoining caravan should not be less than 3m.
    - The point of measurement for porches, awnings, etc, is the exterior cladding of the caravan, excluding the draw bar.
    - An awning should not incorporate sleeping accommodation.
    - Awnings should not face each other or touch.
    - A non-combustible awning will deflect flames and must not be permitted. A combustible awning will burn through and allow heat to dissipate.

- Eaves, drainpipes and bay windows may extend into the 6m (or 5m) space provided the total distance between the extremities of two adjacent units is not less than 5.25m in a 6m space (or 4.5m in a 5m space).

- Where there are ramps for the disabled, verandas or stairs extending from the unit, there should be 4.5m (or 3.5m) clear space between them. Two such items should not face each other in any space. If they are enclosed, they may need to be considered as part of the unit and, as such, should not intrude into the 6m (or 5m) space.
- Fences and hedges, where allowed and forming the boundary between caravans, are permitted provided they are no higher than 1m. The fence should be of a picket fence type. A higher fence is permitted if made from a non-combustible material.

- A garage, shed or covered storage space should only be permitted within the separation distance if it is of non-combustible construction (including non-combustible roof) and sufficient space is maintained around each unit so as not to prejudice means of escape in case of fire. Windows in structures within the separation distance should not face towards the units on either side.

- Carports or a covered walkway should in no circumstances be allowed within the 6m space.

- Private cars, jet skis and motor boats may be parked within the separation distance provided that they do not obstruct entrances to caravans or access around them and they are a minimum of 3 metres an adjacent caravan. Where the 3m space separation cannot be achieved parking should not be permitted within the separation distance.

- Suitably surfaced parking spaces should be provided where necessary to meet the additional requirements of the occupants and their visitors.

- Density shall be calculated on the basis of useable area (ie, excluding lakes, roads, communal services and other area unsuitable for the siting of caravans) other than the total site area.

- Where tents are permitted, 3m clear space should be maintained between the next occupancy.

Table 3 – Criteria Specific to Site Type, taken from[8]

Criteria	**Permanent Residential Caravan Site***	**Holiday Caravan Site**	**Touring Caravan Site**
Minimum separation distance between caravans	6m	5m if aluminium or similar. 6m if plywood or similar, or mixture of permanent residential and holiday caravans	6m
Maximum distance from fire appliance access road	50m	50m	50m
Minimum clear space where there are ramps for the disabled, verandas or stairs	4.5m	3.5m 4.5m if mixture of permanent residential and holiday caravans	4.5m where applicable
Minimum clear space between caravans at corners	3.5m	3.5m	3.5m
Minimum clear space between occupancies from combustibles	3m	3m	3m
Density	50 caravans per hectare	60 caravans per hectare	75 touring caravans or motorhomes per hectare

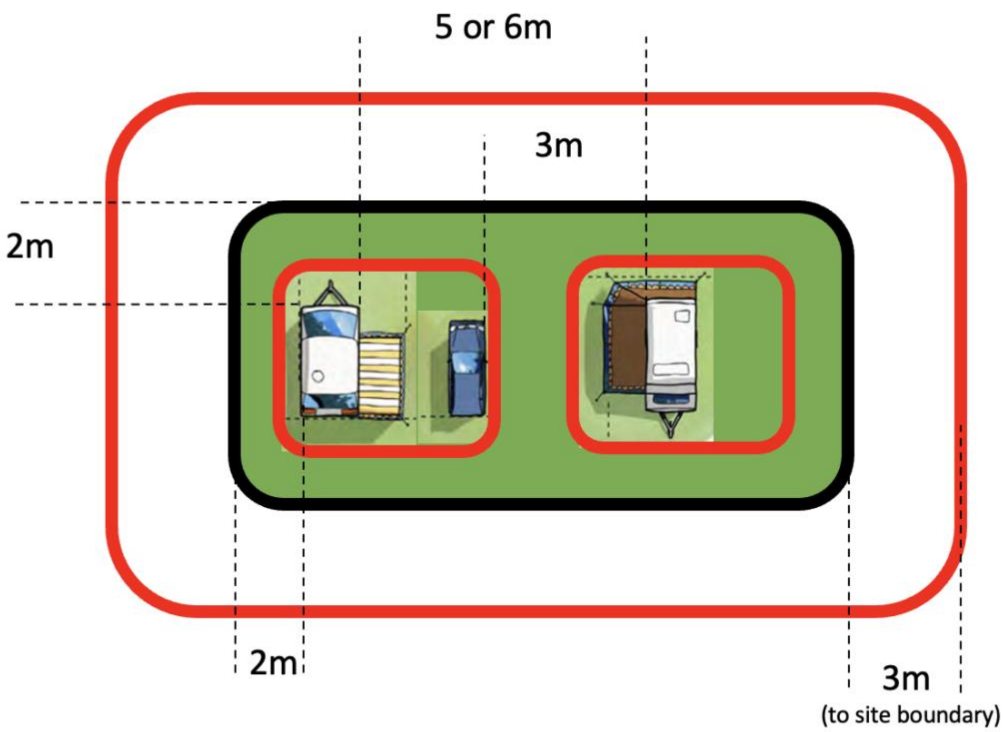

Figure 6 - Authors interpretation of general requirements in the UK

4.6. United States of America (USA):

In the USA, the National Fire Protection Authority has a document standard for vehicle parks and campgrounds[9] which gives some guidance on separation distances as outlined below. New York state was also found to have some separate guidance document with a more detailed list of regulations. In the USA it seems it is similar to Germany, where there is some basic national guidance but each state can if they choose have their own set of rules.

4.6.1. NFPA

NFPA 1194 - Standard for Recreational Vehicle Parks and Campgrounds, states in section 5:

- Camping unit site size. The occupied area of a camping unit shall not exceed 75% of the site area.

- Separation. A stand or structure shall be located at least 10ft (3m) from any other stand or structure.
  - A structure shall be permitted to be closer than 10ft to its stand if is part of the stand or serves the recreational vehicle, recreational part trailer or camping unit using that stand, providing a minimum of 10ft is maintained to any other stand or structure.

[9] NFPA 1194 - recreational vehicle parks and campgrounds

- Tents shall be exempted from the above.

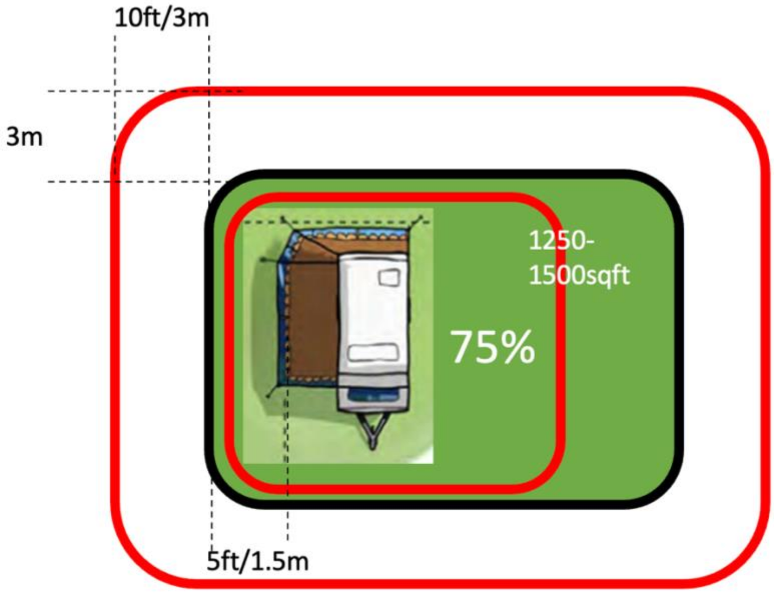

Figure 7 - Authors interpretation of general requirements in the USA

4.6.2. New York

New York rules and regulations Section 7-5.8 - Campgrounds and campsites seem more complicated and are listed as follows[10]:

1. Campsite space requirements. A campsite shall meet the space requirements specified in either paragraph 1, 2, or 3 below as applicable. An agricultural fairground owner may select one or more of these options when establishing campsite sizes within the agricultural fairground.

1) The minimum area per site for campsites that existed prior to March 7, 2001 shall be either: 1,500 square feet; or, in compliance with paragraph (2) or (3) of this **section**.
2) New campsites constructed and existing campsites modified after March 7, 2001 shall be a minimum of 1,250 square feet. These campsites shall be large enough to allow at least a five-foot clearance between the boundaries of the campsite and the exterior surfaces of the camping unit placed on it as well as any add-on structures or appurtenances attached to it, so as to provide for a 10 foot separation distance between camping units on adjacent campsites.
3) The minimum area per site may be less than the requirements specified in **7-5.8**(a)(1) and (2) when:
    i. a separation distance of 10 feet or greater is maintained between camping units including any add-on structures or appurtenances attached to the camping unit; or

[10] https://regs.health.ny.gov/content/section-7-58-campgrounds-and-campsites#:~:text=These%20campsites%20shall%20be%20large,distance%20between%20camping%20units%20on

ii. a separation distance of at least 5 feet is maintained between camping units including any add-on structures or appurtenances attached to the camping units; and

iii. Charcoal grills, gas grills or other open flame cooking devices cannot be used within 10 feet of any camping unit.

iv. Bonfires or recreational fires are prohibited on campsites. Such fires cannot be conducted within 25 feet of any camping unit.

v. Adequate fire extinguishers or other extinguishing equipment shall be readily available to all camping areas. Fire extinguishers, where used, shall be installed and maintained in accordance with the recommendations of the equipment manufacturer and generally accepted standards.

vi. Fire apparatus access roads shall be provided within 300 feet of each camping unit and shall have an unobstructed width of no less than 20 feet and an unobstructed vertical clearance of not less than 13 feet 6 inches.

4.7. Australia:

Australia is similar to Germany and USA, whereby each state seems to have their own regulations on this topic, without much consistency. Guidance was found for Victoria, New South Wales and South Australian states, and is summarised below.

Interestingly, in the Victorian guidelines, there is provided along with these distances a "rationale" (reason why these distances are chosen). These are also added to this section.

4.7.1. Victoria[11]:

- Firefighter access must be:
  - 1.2m in width and *unobstructed* at all times. (It is preferred that the Firefighter Access width is centrally located however this is not essential) and provided with a surface that is *suitably trafficable*.
  - ***Rationale**: Firefighter access is required to be provided by the regulations. Additionally, the relevant fire authority consider that fire separation is also required to achieve an appropriate level of fire safety. Research conducted by the relevant fire authority shows that 1200mm width is required for firefighters to operate effectively. This width assumes the worst-case scenario in terms of firefighter manoeuvrability and tasks (including patient rescue, the use of ladders and fully charged hoses). As caravan parks often have a number of movable dwellings and other permanent structures, there is a trend for movable dwellings to become more home like with occupants staying long term or becoming permanent residents at the park. This can mean that people are living in close proximity to neighbours with a risk of fire spreading to their home.*

- Fire separation must be:
  - 2m in width measured between the external walls of associated *structures*.

- A minimum height of 2100 mm must be maintained throughout the required fire separation width.

- Vegetation and storage between and around *structures* that may contribute to fire spread should be reduced and maintained appropriately.

  - ***Rationale**: One of the key elements of Building Regulations in Victoria is to protect a dwelling from fire the spread and avoid the spread of fire between dwellings. Movable dwellings, caravans, and tents should be treated no differently. Therefore, the fire separation requirements have been based on the Building Regulations and the Building Code of Australia for class 1a single dwellings, which will allow for the combustibility of typical structures found in caravan parks.*

[11] Fire Rescue Victoria: Caravan Park (Interim) Fire Safety Guideline. Approval level: Fire Safety, First issued: 15 January 2021, Review date: 26 March 2021

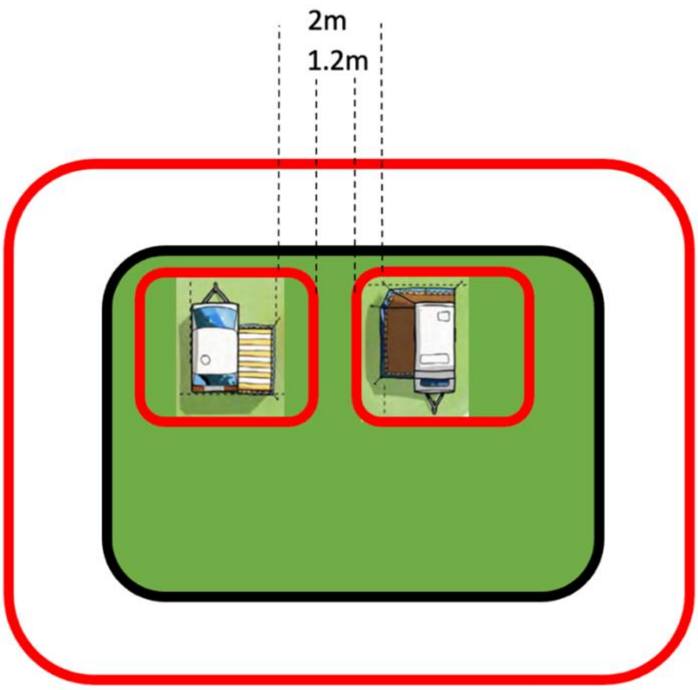

Figure 8 - Authors interpretation of general requirements in Victoria

4.7.2. South Australia[12]:

In South Australia, the regulation is split into *individual sites* and *united sites*. An *individual site* is interpreted as single camps or single caravans, that sit on their own section of the camping area. *United sites* are a set of individual sites put together to form small "islands" of campsites.

Individual *sites*

- *Sites* in a *caravan park* and a *residential park* must not be linked by combustible construction and for individual *sites* a minimum separation distance of not less than 3m must be provided and maintained between adjacent *caravans* (including any attached *annexe*)

- The 3m separation distance must also be provided and maintained between a *caravan* (including any attachment to it, such as an *annexe,* veranda or similar) and–
    - any *tent* on an adjoining *site*; and
    - any adjacent building or structure on another *site*.

United sites

[12] Ministerial Building Standard MBS 003 – Fire safety in caravan parks and residential parks Published by: Department Planning Transport and Infrastructure

- For *united sites*, a clearance distance not less than 4m wide must be provided around each *united site,* and *caravans* and *tents* on sites adjoining the roadway must be set back 1m from the roadway to allow a total clear unobstructed space not less than 6m wide for emergency vehicle access.

- a *united site* may exceed 1000m² if a complying fire hydrant system is provided that will serve each individual *site* on the *united site* and any *sites* adjacent to the *united site*.

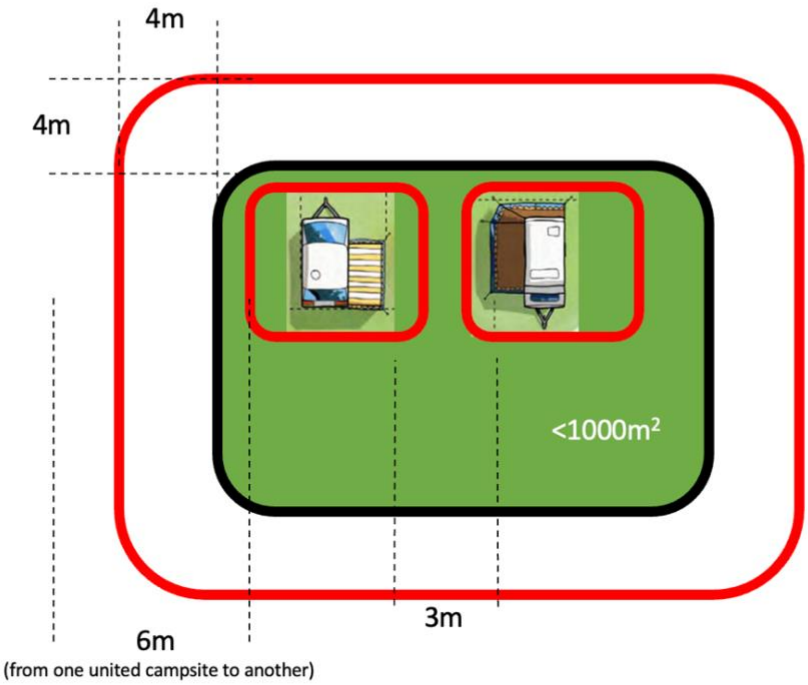

Figure 9 - Authors interpretation of general requirements in South Australia

4.7.3. New South Wales[13]:

In New South Wales (NSW), the Local Government (Manufactured Home Estates, Caravan Parks, Camping Grounds and Moveable Dwellings) Regulation 2021[13] sets the regulation on safety distances:

- A moveable dwelling must not be installed within the following distance of another moveable dwelling:
    - if located on a long-term site: 3m
    - if located on a short-term site or camp site: 2.5m.

- This section does not prohibit the installation of semi-detached relocatable homes on adjoining dwelling sites if they are separated by construction complying with the fire

[13] Local Government regulation – Subdivision 3, section 91: https://legislation.nsw.gov.au/view/whole/html/inforce/current/sl-2021-0461#sec.91

safety and sound insulation provisions in the *ABCB Housing Provisions Standard*, Parts 9.3 and 10.7 for class 1 buildings.

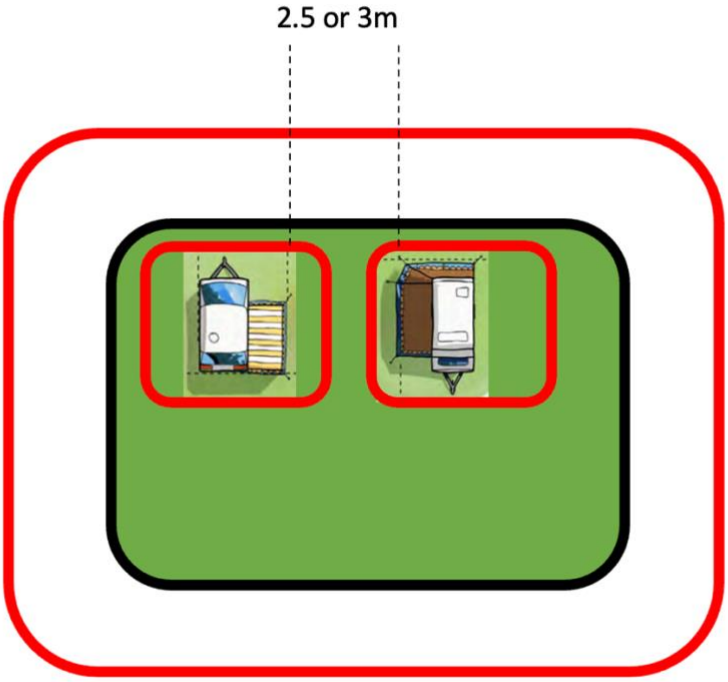

Figure 10 - Authors interpretation of general requirements in New South Wales

4.8. Other:

4.8.1. CFPA-E guideline No. 20:2012 F

The Confederation of Fire Protection Associations in Europe (CFPA-E) has the aim to facilitate and support fire protection activities across Europe. For this reason, they produce their own guidance documents on fire safety topics. It is stated at the beginning of this document that the guidance in this document is heavily influenced from the Finnish regulations, and it is written by Norwegian authors. Hence it is very similar to the guidance in these countries. The most notable addition is the requirement for distance between caravan and neighbouring vehicle.

In section 4.3 “fire precaution rules for the owner of the camping site” the following requirements are an excerpt from this document and are recommended to be applied by the owners of camping sites:

- The ground has to be arranged in such a manner that the free distance between each camping unit is a minimum of 3m, preferably 4m.
- Portable fire extinguishers and/or fire hoses must be placed around the site. The traveller distance to the fire extinguisher should not exceed 25m.

- For every 1000m^2 it is recommended to make an open area of at least 6m width to the next section.

- The camping site should be divided into blocks with 30 places for vehicles, maximum 60 tents, giving each car with trailer a space of minimum 100m^2 and each caravan a space of minimum 80m^2. The distance between the blocks should be a minimum of 8m.

- Each block in the site should be divided into 3 units, each with space for 10 vehicles and with a minimum distance of 5m between each unit.

- Minimum distance between a caravan and a neighbouring vehicle or awning should be 1.8 metres.

4.8.2. Russia:

In “ГОСТ” “Государственный Стандарт" which can be translate as "State Standard" for Russia. Tourist services. Camping-sites. General requirements (ГОСТ Р 58187-2018)

- If the campsite provides places for fires, they must be located in a safe place at a distance of 25-50m from trees, bushes, structures, parking lots, etc.

- The fire separation distance of 1.5m adopted in the standards between tents in a camping site may guarantee their fire safety. When using luminous (term “luminous” is assumed to mean some sort of fire retarded paint) paints, the fire separation distance between the fastening elements of the tents can be set at 1.2 m, as recommended for caravan parks in Australia."

4.8.3. Italy, Japan, Latvia and Turkey:

Searches in these countries were done and no specific regulations were found.

5. Mapping of Materials and Design

There have been significant advancements in materials used in caravans over the years. In this section we will briefly overview the differences between “old” (1990s and before) and “new” (>2000) styles of caravan. The focus of this section is on caravan materials, tenting materials for the purposes here have been ignored.

There are two main forms of construction that caravan manufacturers tend to use. The first is known in some countries as the traditional “stick and tin” construction which dates back to the 1940s[14]. The construction here involves laying aluminium cladding or composite panels over a timber (may be metal as well, but most commonly wood) frame.

The second and newer process involves assembling structural composite sandwich panels. Building caravans with composite sandwich panels, usually built in layers of fiberglass – foam insulation – fiberglass, is more efficient and is increasingly favoured over traditional stick and tin builds by

[14] https://linersupply.com.au/what-materials-make-a-difference-in-caravan-construction/

manufacturers and consumers. This is largely due to factors such as; weight, durability and cost. Caravans built with wood are heavier, harder to clean and more susceptible to rot, water damage and warping. A composite caravan, on the other hand, is more durable, lightweight and resistant to weather[16].

Below gives as overview of the basic differences between "old" and "new" caravans[15]:

- Construction Materials:
  - old: Caravans from these decades typically used wood, steel or aluminium frames for their structure, which made them heavier.
  - new: Modern caravans often employ lightweight materials such as aluminium or fiberglass-reinforced composites for their frames, which reduces weight and increases fuel efficiency.
- Exterior Cladding:
  - old: Many older caravans had aluminium or steel cladding, which required more maintenance due to rust and paint issues.
  - new: Modern caravans often use materials like fiberglass or high-quality plastics for their exteriors, which are more durable, require less maintenance, and resist corrosion.
- Insulation:
  - old: Often used traditional insulation materials like fiberglass batting, or older foam types (e.g. PU).
  - new: Modern caravans incorporate advanced insulation materials, including closed-cell foams and thermal reflective barriers, which offer superior insulation properties and help maintain comfortable interior temperatures.
- Interior Materials:
  - old: Interiors of older caravans were commonly adorned with wood veneers, particleboard, medium-density fiberboard (MDF), or plywood for interior cabinetry and furnishings. These materials were heavy and susceptible to moisture damage.
  - new: Modern caravans tend to use lighter, more durable materials like synthetic laminates, vinyl, polyethylene (HDPE) and lightweight composites. These materials are more resistant to moisture, reducing the risk of rot and mould.
- Windows and Seals:
  - old: Often had single-pane windows and seals that were less effective at insulation and weatherproofing. Windows were glass or more commonly made of acrylic.
  - new: Modern caravans typically use double-glazed windows made of ABS or polycarbonate and have improved sealing materials, enhancing insulation. These changes may also influence the burning behaviour of new caravans, as typically windows are seen as the first part to fail in fire tests performed on older caravans.
- Technology Integration:
  - Now: Modern caravans often include advanced technology such as LED lighting, solar panels, touchscreen control systems and battery packs, which were not common in the older caravans. These may also have a significant impact on the fire/burning behaviour of modern caravans compared to the older styles.

6. Li-ion Battery risks in Caravans/Motorhomes

One significant difference between older caravans and more modern caravans besides the materials used, is the usage of batteries, specifically li-ion batteries. these batteries can be used all over the

[15] https://rvdaily.com.au/caravan-construction-stick-and-tin-vs-composite-panels/

caravan for various reasons, as a method of power for appliances within the caravan, for energy storage from PV cells on the roof, or in the form of e-mobility devices and other electronic appliances.

Due to their widespread use in today's society, these batteries add a new dimension and come with certain new risks[17], [18]. This may be especially important to consider in the context of caravans or mobile homes due to their popularity as an energy storage system, the confined spaces involved, the potential for movement and vibration and the lack of regulation with regards to safe installation.

Some issues associated with li-ion batteries include:

- Overheating: Li-ion batteries can overheat if they are charged or discharged too quickly or if they are subject to extreme temperatures. This can lead to a thermal runaway (TR), where the battery generates even more heat, potentially causing a fire.
- Physical Damage: If the battery is damaged, punctured, or undergoes physical stress, it can cause internal short circuits, leading to overheating, TR and potential fire hazards.
- Charging Issues: Improper charging, using incompatible chargers, or overcharging can cause Li-ion batteries to overheat, go into TR and potentially catch fire.
- Battery Aging: As Li-ion batteries age, their internal components degrade, which can increase the risk of malfunctions and potential fires.
- Poor Installation: Incorrect installation, inadequate ventilation, or not following manufacturer guidelines for setup and use can increase the risks associated with these batteries.

Some of these issues may be mitigated through use quality batteries from reputable manufacturers, employing proper battery management systems and monitoring equipment, ensuring proper ventilation and temperature control in the area in which they are stored/installed. However as there is little current guidance on this, and especially with regards to the manufacturing of caravan, it will be difficult to control/regulate. With regards to scientific literature, there is a wealth of papers on li-ion batteries and their fire behaviour, however nothing specifically with regards to risks associated with caravans could be found.

Some additional considerations with regards to batteries is also the potential to release hazardous gases, and in the confined space of a caravan this has potential to be a significant risk to occupants and for deflagration/explosion, in a study by RISE Norway[19] states: *Lithium-ion batteries undergoing a thermal event typically emits 1-3 litres of gas per ampere-hour (Ah) at 26 °C and 3.7 volts (V), depending on battery chemistry and state of charge (SOC). Venting from lithium-ion batteries contains carbon dioxide, flammable components such as carbon monoxide, various hydrocarbons, methanol and hydrogen, as well as toxic components such as hydrogen fluoride, hydrogen chloride and hydrogen cyanide. The relatively large proportion of flammable gases (e.g. around 30% hydrogen) makes venting from lithium-ion batteries an explosion hazard*. These are some significant risks that have not previously been well considered.

Some recommendations could be given by e.g. MSB, to raise awareness of the potential risks involved, also providing guidance on e.g. following recommended charging practices and use compatible charging equipment and recommending to regularly inspect batteries for physical damage or signs of wear, safe storage etc. Caravan owners need to be aware of these safety concerns and be informed about how to handle emergencies related to battery fires going forward. In addition, as the scientific literature is lacking, it would be a recommendation of this report that some further investigations should be initiated within this area.

7. Conclusion

Taking in all the information provided in this report, there is a large amount of uncertainty involved in providing recommendations on what separation distances should be to reduce the risks of fire spread between caravans and camping units. Regulations and guidelines from other countries show little consistency and a large spread in the recommended values. Variations between 2m up to 8m is seen in the country recommendations reviewed in this report, and the current guidance provided in the Swedish regulations sits just under the middle taking 2m and 8m as the extreme values. The scientific literature shows there is a lack of thorough, systematic investigations into this topic, which poses the question as to how regulations in each country were developed. The only country where evidence could be found of research-based recommendations was from the U.K. which based their regulations on the study conducted by BRE [2] however given its aged, these could now be considered outdated data. Finland guidance also refers to previous research in their documents, however these could not be found. The Finnish documents also acknowledge the change in construction materials of caravans in the recent years, and that this should influence the given outcomes of a fire in these scenarios, but nothing further is noted. Considering also the new risks associated not only with the newer construction materials but also the introduction and likely increased usage of battery systems within caravans and other forms of mobile home, the requirement for further research on this topic is the general recommendation of this report.

8. References

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9. Appendices

Appendix 1: Links to videos

- https://www.youtube.com/watch?v=qft4q_urYww
- https://www.youtube.com/watch?v=aLrOK6A_fKo (top gear)
- https://www.youtube.com/watch?v=v2ieENNHxnc
- https://www.youtube.com/watch?v=kKiSQbWpJfw
- https://www.youtube.com/watch?v=BIyj-MrD4y0
- https://www.youtube.com/watch?v=KouweLZYUI8
- https://www.youtube.com/watch?v=8o5ecD1pHBw (Norwegian fire tests)
- https://www.youtube.com/watch?v=Krw-8xzBTJM (Norwegian fire tests)

Appendix 2: Full list of papers from Section 3, step 5:

Authors	Title	Year	Source title	Volume	Issue	DOI	Document Type	Source	EID
Li H.	Research on Mobile Caravan Insurance Recommendation Method Based on Machine Learning	2021	Proceedings - 2021 International Conference on Artificial Intelligence, Big Data and Algorithms, CAIBDA 2021			10.1109/CAIBDA53561.2021.00010	Conference paper	Scopus	2-s2.0-85116717725
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