MAIN CAUSES OF CARGO FIRE INCIDENTS IN RO-RO SPACES: AN ANALYSIS OVER THE LAST 25 YEARS

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ABSTRACT
The FIRESAFE study from EMSA revealed that 90% of all ro-pax ship fires are initiated in the carried cargo (vehicles and cargo units), which can be everything from brand new to poorly maintained, rebuilt, or unsafe. Today, all cargo (except dangerous goods) is loaded without consideration to the hazards they pose, leaving much room for fire prevention. This paper focuses on the analysis of available historical data related to fire accidents produced inside ships. The objective is to find out what the main causes and their origins are. The methodology includes the following steps: (1) the compilation of information from several maritime sources, (2) the corresponding homogenization based on preliminary outcomes of LASH FIRE (H2020 funded project, Grant Agreement #814975, in which this publication is framed), (3) a brief overview on the design of the underlying database which supports the analysis and finally, (4) the main conclusions. The analysis considers not only the type of ship and cargo (classified as dangerous or non-dangerous goods, if it is transported in a vehicle or not and, in that case, what type of vehicle, etc.) but also the ro-ro space where it was located. The resulting information is used to identify patterns in the root causes (electrical, mechanical, overheating, etc.) in order to create knowledge that can be further used for the development of innovative solutions for the implementation of fire hazard management.
Keywords: ignition prevention, risk analysis, fire safety, stowage.

1 INTRODUCTION

Safety is a key parameter in any topic, and maritime transport is not an exception. Nowadays, there is an increasing concern from the International Maritime Organization (IMO) and other regulatory bodies to improve safety, especially on reducing the risk of fires on board ro-ro ships. Proof of this is that in 2019 IMO's sub-committee [1] held a meeting with the aim of creating guidelines focused on fire safety on ro-ro vessels

Transportation of ro-ro cargo entails lot of fire hazards for the vessel because vehicles have several elements such as the engine, fuel tanks or electrical systems that could cause an ignition [2]. FIRESAFE study showed that 30% of fires in ro-ro ships are originated on vehicle decks and 90% of these were originated in the cargo transported [3].Therefore, ro-ro ships need special attention regarding to fire safety. Besides this, these types of vessels lack compartmentalization of cargo space, which means that in case of fire on a cargo unit, the entire deck is potentially threatened.

However, current cargo placement in ro-ro spaces is not optimal against fire hazards. There have been several fire incidents in recent years, originated mainly in those vehicles transporting the cargo [4].These kinds of incidents concern not only from the economic loss perspective but also the risk they represent for human beings.

In front of this scenario, this paper describes and evaluates the main causes of cargo unit fires over the last 25 years. The work is presented as the first step to solve the problem. To do so, it is necessary to know what is being transported and the risks involved in cargo units.

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Cargo other than dangerous goods have not been regulated so far; no recommendations on how they should be transported either. This situation drives to operator-specific standards for a safer transport based on their own experiences.

This article aims at analysing historical data and identifying patterns, main causes and problems derived from the lack of information about the loads to be transported to establish a knowledge baseline of the problem for future solutions preventing cargo fires on ro-ro spaces. The approach of the methodology used involves the following steps:

1. Since needed information is not available as required, firstly is the search for different sources, to analyse them to gather as much relevant information as possible and discarding and filtering all unnecessary information. At this point, all the data is formatted in a spreadsheet (user-friendly) and the process is done manually.
2. Transformation to a structured format oriented to speed up the access of the information by other software components (machine-friendly).
3. Once the cargo fire risk database has been finalized, it is analysed considering accident factors such as main origin, causes, where it occurred (type of deck: open, closed or weather) or year among other relevant characteristics.

2 DATA COLLECTION

In order to obtain an accurate and realistic analysis based on historical data, it is of paramount importance to collect all incidents that could be relevant and to create a solid background. Thus, an intense work has been done looking for and gathering incidents, accidents or reports coming from several heterogeneous sources of information.

Data selected must fulfil two conditions: (a) the fire origin must be located in a ro-ro space, and (b) the fire must be started in the vehicle or the cargo transported by (i.e. fires started in the engine room of the ship are discarded).

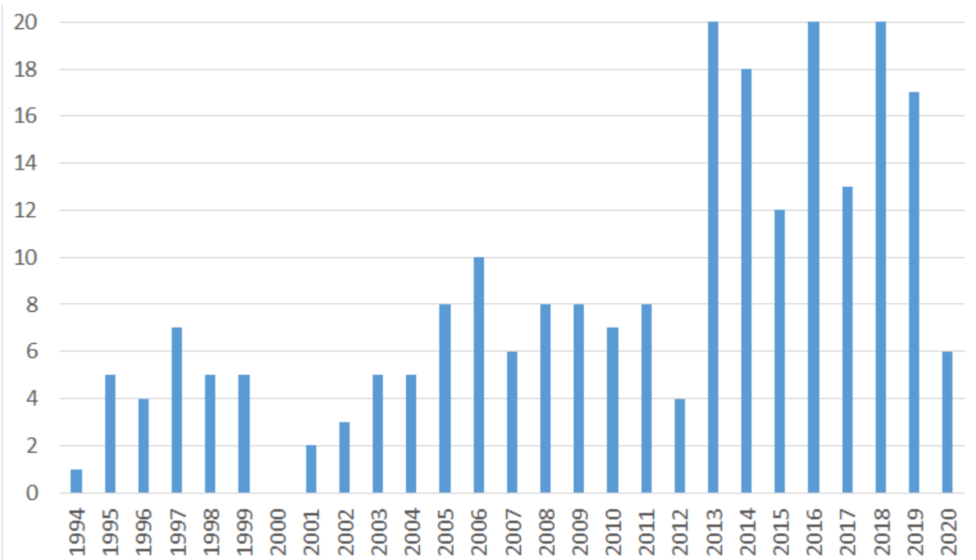
Sources include public and private organizations, ship operators, research institutes and journals; all of them are briefly described below:

1. FSI 21/5: Document provided by IMO [5] which offers a wide list of maritime accidents in ro-ro passenger ships from 1994 to 2011.
2. GISIS: Global Integrated Shipping Information System [6] is an information system provided by IMO that, among other services, provides a collection from several marine casualties and incidents.
3. Ship operators: The representatives from the Maritime Operators Advisory Group (MOAG) of the LASH FIRE project [7], gave access to incidents or near-miss related information in the ro-ro spaces from their own databases.
4. ForeSea [8]: Information system used in Sweden and Finland to record accidents, incidents or near misses at sea.
5. Official organizations in Mediterranean countries: Research in official organizations from Mediterranean countries such as CIAIM (Comisión Permanente de Investigación de Accidentes e Incidentes Marítimos) [9], HBMCI (Hellenic Bureau for Marine Casualties Investigation) [10] or MTIP (Ministry for Transport, Infrastructure and Capital Projects) [11] has been performed to complement the rest of sources, where only northern locations were found.
6. EMCIP: The European Marine Casualty Information Platform [12] is a database and a data distribution system, also connected to GISIS, operated by EMSA (European Maritime Safety Agency), the European Commission and the EU/EEA Member States.
7. Other sources: Apart from the above, several sources such as journals (e.g. *Journal of Maritime Research*) or private companies' reports have been analysed. The main

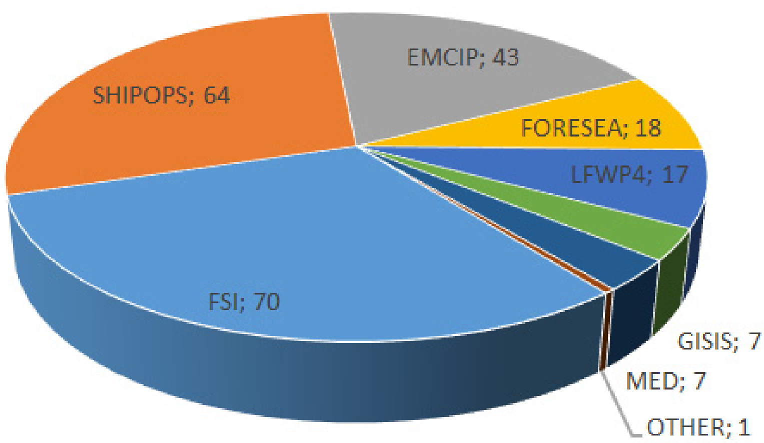
purpose of these sources was to complete unknown information from incidents already recorded although they also provided some new incidents.

Project-related sources were also included: outcomes from an internal workshop (several marine casualties in ro-ro spaces, some of them already covered by FSI and GISIS but contributing with additional details) or internal fire investigation database from RISE, the Research Institutes of Sweden [13], who plays the coordinator role in the Consortium of LASH FIRE project.

At the end of the process, about 230 records have been obtained; existing duplicates have been considered only once and have been assigned to that source where more detailed and accurate information was found (Fig. 1).



(a)



(b)

Figure 1: Summary of collection. (a) Yearly distribution; and (b) Incidents per source.

Nevertheless, this work is not limited to gathering records but also in classifying them with respect to the fire origin and cause, and merging the information provided from different sources to perform a single and consistent database.

The first classification variable is the fire origin, key element to perform a risk-based analysis, as probability of ignition occurrence may vary significantly. The analysis distinguishes between refrigeration units (commonly referred as reefers), conventional vehicles (trucks, cars and buses), special vehicles (includes tractors, forest vehicles, …), new energy carriers (those vehicles which use alternative fuels, including electricity) and, due to its specific properties, dangerous goods, regardless of not being a vehicle.

The second level of classification is the cause of the fire, which gives information about the factors that lead to an increase of the probability of ignition. Detecting these conditions allows considering them as potential-ignition factors in the risk analysis. Some of the most common fire causes are electrical faults in cables or connections (especially for reefer units), electrical faults (in the unit, cabin or in the engine compartment), mechanical faults, overheating (in the chassis or in the engine compartment), engine leakage of flammable liquid or ignition in the cargo itself.

In addition to the abovementioned, up to almost 20 relevant data fields from each incident have been collected like the date and location of the incident, the severity, what goods the vehicle was transporting (if any), what goods were transported by nearby vehicles or if the origin vehicle was connected (and charging) when the ignition occurred. For those reports, extra information has been gathered such as the type of vessel (ro-ro, ro-pax or car-carrier), the deck (which one and type) or if the vessel was loading, on passage, or unloading. In those cases, where dangerous goods were involved, their IMDG code (The International Maritime Dangerous Goods Code) was also included in the database.

3 DATABASE CONSTRUCTION

While the previous step aimed for the most relevant data compilation possible, at this stage of the methodology the objective is to structure the information in such a way that becomes agile for further exploitation, as described later.

More in depth, the next list enumerates the main actions performed:

1. Using a macro developed with Visual Basic for Applications, a new tab is filled with all the data in a tabular way. The objective is to prepare the data to be used to populate the final database.
2. A second macro exports the tab generated in the previous step to a comma separated values file.
3. Finally, a script developed in Python dynamically creates the database based on the corresponding relational model and populates it with a selected set of information from the file obtained in the previous step.

Fig. 2 graphically depicts this process and shows which steps are interactive (requires user interaction) and which are not (just launch an automatic process).

The so-called cargo fire hazard database is based on a relational model, which is a methodological approach where the information is represented in terms of tables and relationships between these tables. While tables store entities or logical units of information, relationships define interaction or association between tables; each table contains a set of attributes, each of them, featuring a relevant characteristic of the logical unit of information.

Such a structure not only provides a better organisation of the data but a way to speed up queries against the database in order to retrieve information that can be used for many purposes. Queries can be performed against one or more tables, extracting a final set of records composed of logical and mathematical operations between involved attributes.

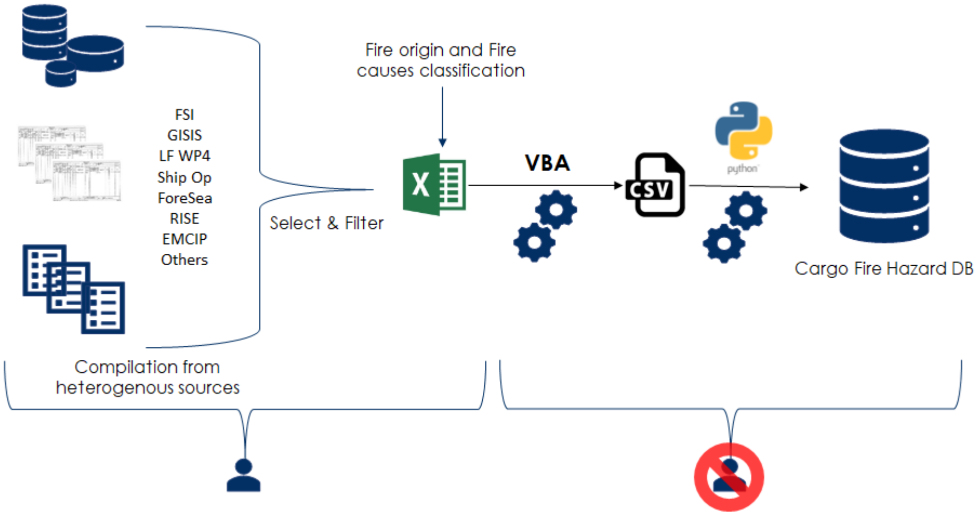


Figure 2: Workflow of the methodology (data collection and database construction).

3.1 Implementation

Using a relational model does not imply a unique implementation because there are lot of both free and commercial solutions, each of them offering different options in terms of prices, licensing, portability, scalability or technical support. In the context of the project where these tasks have been developed, the following requirements, among others, were taken into consideration:

- Development frameworks, programming languages and protocols, as mainly examples, must be free and open, if possible.
- Availability in the most common operating systems and easy to install and/or deploy, ensuring portability.
- Products fast to learn for future maintenance purposes by third-party staff.

Finally, the selected platform is composed of Python as programming language and Sqlite as the database management system (DBMS). Python is an interpreted, high-level, general-purpose object-oriented programming language emphasizing code readability for large-scale projects, including a comprehensive standard library. Sqlite is a relational database management system (RDBMS) which, in contrast to many other systems, it is not a client-server-based engine. It implements most of the SQL (structured query language) standard while ACID (atomicity, consistency, isolation and durability) properties of database transactions are guaranteed. Its source code is in the public domain and free of charge to everyone to use for any purpose.

4 METHODOLOGY OF DATA ANALYSIS

From the database constructed, an exploratory analysis is carried out to select the variables to be used to apply the multiple correspondence analysis. Once applied, the different correlations or patterns are searched for/analysed to find out the relationships between the variables.

R Studio software (version 4.1.0) is used for the analysis. The MCA has been performed using the MCA (multiple correspondence analysis) function (FactoMineR package). The R package factoextra is then used to produce a ggplot2 based visualisation of the MCA results.

4.1 Correspondence analysis (CA)

Correspondence analysis [14] provides tools for the analysis of the associations between rows and columns of contingency tables. A contingency table is a two-entry frequency table where the joint frequencies of two qualitative variables are reported. For instance, a (2 × 2) table could be formed by observing, from a sample of n individuals, two qualitative variables (in general they are s variable). The table reports the observed joint frequencies. In general ($n \times s$) tables may be considered.

The main idea of CA is to develop simple indices that will show the relations between the row and column categories. These indices will define what is the weight a column has for a row category and vice versa. CA is also related to both issues of reducing the dimension and decomposing the table. The idea is to extract the indices in decreasing order of importance so that the main information of the table can be summarised in spaces with smaller dimensions.

Contingency tables are very useful to describe the association between two variables in very general situations. The two variables can be qualitative, in which case they are also referred to as categorical variables. Each row and each column in the table represents one category of the corresponding variable. The entry n_{ij} in the table N (with dimension ($n \times s$)) is the number of observations in a sample which simultaneously fall in the ith row category and the jth column category, for $i = 1, \ldots, n$ and $j = 1, \ldots,$ s. For notational simplicity [15] the matrix is first converted to the correspondence matrix $\boldsymbol{P}$ by dividing $\boldsymbol{N}$ by its grand total $n = \sum_i \sum_j n_{ij} = 1^T N 1$ (the notation 1 is used for a vector of ones of length that is appropriate to its use; hence the first one is $n \times 1$ and the second is $s \times 1$ to match the row and column lengths of $\boldsymbol{N}$). Correspondence matrix:

$$P = \frac{1}{n} N. \tag{1}$$

The following notation is used:

- Row and column masses:

$$r_i = \sum_{j=1}^{n} p_{ij}, \qquad c_j = \sum_{i=1}^{s} p_{ij},$$
$$i.e.,\ r = P1, \qquad c = P^T 1. \tag{2}$$

- Diagonal matrices of row and column masses:

$$D_r = diag(r) \quad \text{and } D_c = diag(c). \tag{3}$$

Note that all subsequent definitions and results are given in terms of these relative quantities $P = \{p_{ij}\}$, $r = \{r_i\}$ and $c = \{c_j\}$, whose elements add up to 1 in each case. Multiply these by n to recover the elements of the original matrix N: $np_{ij} = n_{ij}$, $nr_i = i$th row sum of N, $ncj = j$th column sum of N.

The computational algorithm to obtain coordinates of the row and column profiles with respect to principal axes, using the singular value decomposition (SVD), is as follows (eqns (4)–(10)):

Step	Description	Equation	
1	Calculate the matrix S of standardized residuals	$S = D_r^{-\frac{1}{2}}(P - rc^T)D_c^{-1/2}$	(4)
2	Calculate the SVD of S	$S = UD_\alpha V^T$ where $U^TU = V^TV = I$ where *Dα* is the diagonal matrix of (positive) singular values in descending order: *α1* ≥ *α2* ≥.	(5)
3	Standard coordinates Φ of rows	$\Phi = \mathrm{D}_\mathrm{r}^{-\frac{1}{2}}V$	(6)
4	Standard coordinates Γ of columns	$\Gamma = D_c^{-\frac{1}{2}}V$	(7)
5	Principal coordinates F of rows	$\mathrm{F} = \mathrm{D}_\mathrm{r}^{-\frac{1}{2}}UD_\alpha = \Phi D_\alpha$	(8)
6	Principal coordinates G of columns	$\mathrm{G} = \mathrm{D}_\mathrm{c}^{-\frac{1}{2}}VD_\alpha = \Gamma \mathrm{D}_\alpha$	(9)
7	Principal inertias λk	$\lambda_\mathrm{k} = \alpha_k^2, \quad k = 1, 2, \dots, K$ where $K = \min\{n-1, s-1\}$	(10)

The rows of the coordinate matrices (from step 6 to step 9) refer to the rows or columns, as the case may be, of the original table, while the columns of these matrices refer to the principal axes, or dimensions, of which there are min {n−1, s−1}, i.e., one less than the number of rows or columns, whichever is smaller.

That is, the weighted sum-of-squares of the principal coordinates on the *k*th dimension (i.e., their inertia in the direction of this dimension) is equal to the principal inertia (or eigenvalue) $\lambda_k = \alpha_k^2$, the square of the *k*th singular value, whereas the standard coordinates have weighted sum-of-squares equal to 1. All coordinate matrices have orthogonal columns, where the masses are always used in the calculation of the (weighted) scalar products.

The inertia is also the sum of squares of the singular values or the sum of the eigenvalues:

$$\text{inertia} = \sum_{\mathrm{k}=1}^{K} \alpha_k^2 = \sum_{k=1}^{K} \lambda_k. \quad (11)$$

Finally, the coordinate matrix is projected onto the principal axes where the greatest inertia accumulates. Theoretically, the first two dimensions of this matrix (1–2) are projected, but more can be projected, usually up to five axes. Then, the different combinations between them are made for their projections. Once they are done, the pertinent conclusions are drawn.

The extension of simple correspondence analysis to the case of several nominal variables (multidimensional contingency tables) is called multiple correspondence analysis and uses the same general principles as the previous technique.

4.2 Multiple correspondence analysis (MCA)

The MCA [16] is applied to contingency tables where there are (n) individuals in rows and (s) categorical variables with (pi = 1, 2, …, s) mutually exclusive and exhaustive in columns (s).

The data table has the form:

$$Z = [Z_1, Z_2, \dots, Z_s]\text{: where } Z_i \text{ is a matrix } (n \cdot p_i)\text{, such that:}$$
$$\begin{cases} 1 \text{ if the } i\text{th individual chooses modality } j \\ 0 \text{ if the } i\text{th individual does not choose modality } j \end{cases}$$

The multiple correspondence analysis is based on performing a correspondence analysis on the so-called Burt matrix: B = Z'Z

The Burt of MCA is the application of the basic CA algorithm to the matrix B, resulting in coordinates for the J categories (B is a symmetric matrix).

5 RESULTS

To begin with, the database will be quickly analysed to find out what information it contains. To do this, a summary is made, which can be seen in Fig. 3.

```
          Fire.origin.1        Fire.origin.2              Fire.cause      Year               Severity     Type.of.vessel
Conventional vehicle:67   Truck           :39   Cargo               : 2   2013    :11   Less serious   :11   Car carrier: 6
Dangerous goods     :10   Value           :30   Collision           : 1   2016    :10   Marine incident:30   Ro-pax     :76
New energy carrier  : 1   Car             :25   Electrical          :77   2014    : 9   Near miss      :20   Ro-ro      :14
Reefer unit         :30   RVs             : 8   Leakage             : 8   2008    : 7   Serious        : 6   NA's       :21
Special vehicle     : 9   Flammable liquid: 4   Mechanical failure  : 2   2015    : 7   Very serious   : 2
                          Bus             : 3   Overheating         :26   (Other):72   NA's           :48
                          (Other)         : 8   Spontaneous ignition: 1   NA's    : 1
          Location     Occurred.when Closed.or.open Dangerous.goods Code.dangerous.good Was.charging.
Mediterranean Sea: 9   Arrival    : 7   Closed :84     No :107         3       :  4        NA   : 4
Baltic Sea       : 7   Departure :10   Open    : 1     Yes: 10         1       :  1        No   : 2
North Sea        : 4   In port    :11   Weather: 3                     2#2,5#1:  1        Yes :25
English Channel  : 2   Loading    :11   NA's   :29                     4#1     :  1        NA's:86
Adriatic Sea     : 1   On passage:69                                  4#3     :  1
(Other)          :21   Unloading : 6                                  (Other):  2
NA's             :73   NA's       : 3                                  NA's   :107
```

Figure 3: Database summary.

Analysing the database (see Fig. 3), it can be observed that most of the variables have NA's or omitted values. For this reason, it was decided to perform the advanced statistical analysis with FireOrigin1, FireOrigin2 and FireCause, since all possible data are available.

Once the variables are selected to start the analysis, they are defined as active variables in the MCA First, the accumulated inertia (variance explained by the three variables) is calculated for all axes, where there are 21 dimensions. Fig. 4 shows the 10 dimensions with the most inertia only the first 10, which account for 90.2% of the total inertia.

Based on the above information, the variables in the first 4 dimensions will be projected, since 67.3% of the variance is explained. The other dimensions, individually speaking, contribute very little information (<6%) to the database. For this reason, it was decided to interpret only the first four dimensions.

In order to analyse each of the dimensions, two steps will be carried out: first, project the three selected variables to dimensions 1 and 2 and second, the same for dimensions 3 and 4, where the cumulative inertia in dimensions 1 and 2 is 43.3%, and in dimensions 3 and 4 it is 24%.

First, the three variables will be projected in the 1 and 2 dimensions. The projections can be seen in Fig. 5.

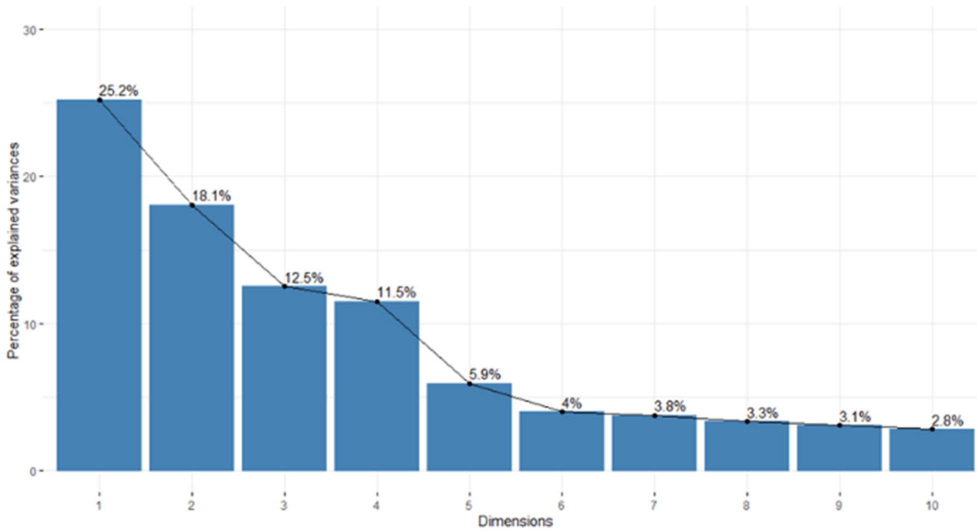


Figure 4: Inertia of the first 10 dimensions (90.2% of variance explained).

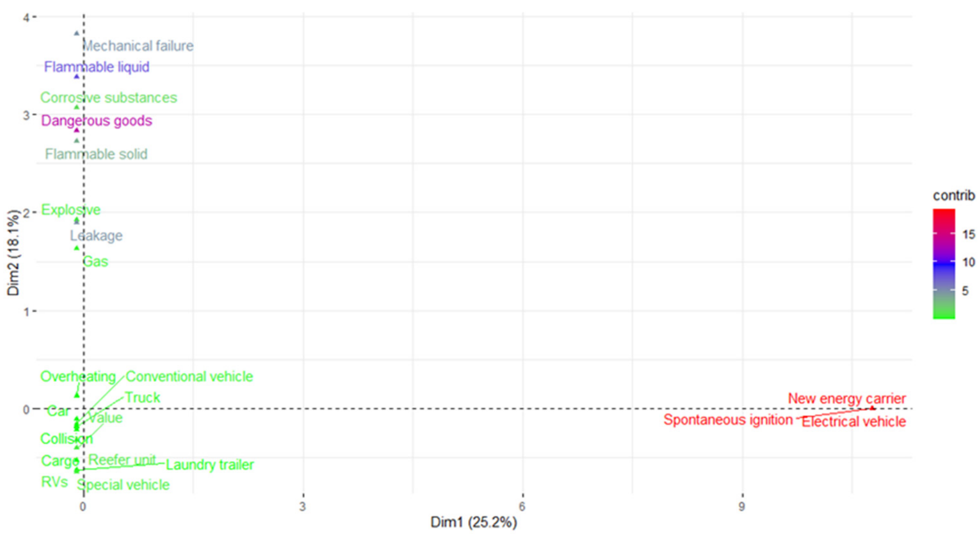


Figure 5: Projections of variables in the first two main axes (43.3%), according to the contributions of their categories.

Fig. 5 shows the categories of the variables according to their contribution in the first two axes (dimensions) from red colour (more important) to green (less important). In the first dimension, the combinations of the following categories are clearly highlighted: new energy carrier, spontaneous ignition and electrical vehicle. In the second axis would be the combination of: dangerous goods, flammable liquid, flammable solid and mechanical failure.

Secondly, the projection will be made in dimensions 3 and 4 (see Fig. 6). The Fig. 6 depicts how dimension 3 is a combination between two categories: Special vehicle and RVs. The fourth dimension is a mix of the categories: value, reefer unit and conventional vehicle.

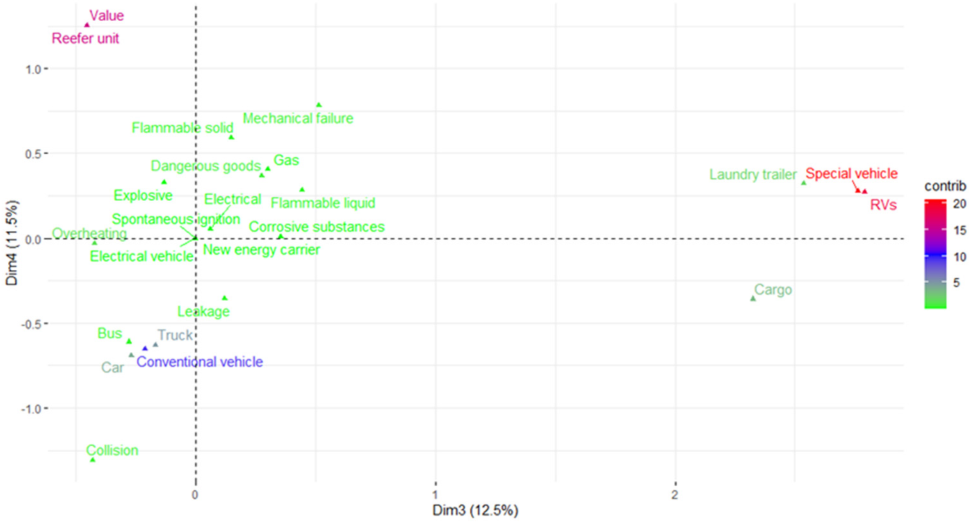


Figure 6: Projections of variables in the three and four main axes (24%), according to the contributions of their categories.

Please note that when FireOrigin1 is reefer unit there are not different options for FireOrigin2, so just value is used in the latter to avoid null values or propagating the same value or RU, for example. It is just a decision on the database design with no relevance on the results.

6 CONCLUSIONS

As a first general conclusion, limitations on the availability of the data (size of the sample, not open-access or not free) lead to a decrease of the quality of the outcomes of the analysis.

From data collection perspective, since there is no standard regarding how information for incidents should be reported, many heterogeneous sets of attributes can be found depending on requirements, functionalities and what is the purpose of the data set. Therefore, a previous time-consumption homogenization of the taxonomies was required. To give some examples:

- Fields describing the ship type usually rely on categories that, again, depend on the source, making it difficult a direct merging.
- Definition of severity include values that depend on a subjective assessment, which may imply a certain level of bias in the results (to be more accurate, in the maritime context, there are clear definitions of the severity level but these definitions are more qualitative than quantitative).

Nothing remarkable from the software engineering point of view, which is agnostic to the abovementioned issues:

- Database design is based on a relational model, which can be extended as needed or implemented with a wide variety of DBMS platforms.
- Using automatisms by means of macros or scripts allows scalability without additional effort in case of updating the starting compilation with new information.

In terms of the MCA data analysis, the results obtained can be summarised as follows:

- In Fig. 5 the first dimension (Dim1 – horizontal axis) shows the combination of the categories new energy carrier, electrical vehicles and spontaneous ignition for the variables FireOrigin1, FireOrigin2 and FireCause. This result represents what happens in the real world, where fires in electrical vehicles are originated in their batteries due to an unexpected and unpredictable thermal runaway.
- Also, in Fig. 5, the second axis shows the combination of: dangerous goods, flammable liquid, flammable solid and mechanical failure. Considering that mechanical failure also includes friction between parts, the combination reveals how important is lashing of dangerous goods during the stowage process to avoid displacement of the units. All incidents of the database belonging to this combination reported ignition as a result of an increase of the temperature of mechanical parts close to flammable goods. Friction was created by means of repetitive movements of the unit due to bad weather conditions.
- In Fig. 6, the third dimension (Dim3 – horizontal axis) shows that the most frequent combination is composed of special vehicle and RVs (recreative vehicles like mobile homes) as FireOrigin1 and FireOrigin2. Into this combination, the most usual fire cause comes from the cargo (the nature of these vehicles drives to a wide range of items that could represent a fire hazard) and, secondly, due to electrical problems, which represent a subset of the previous, including all kind of gadgets that have electricity as their main power supply like stoves, ovens or fans with non-standard installations.
- Also, as it is shown in Dim4 (vertical axis) in Fig. 6 that there is a strong relation between conventional vehicles (FireOrigin1) and both car and truck (FireOrigin2) which makes sense since these two types of cargo units are the most usual being transported in ro-ro ships.
- Finally, for both reefer units and conventional vehicles, the causes are significantly variable, resulting on a point cloud (green colour). Thus, no definitive conclusion can be extracted from the analysed sample. However, as additional conclusion, the most causes are electrical (28%), leakage (23%), overheating (10%) and spontaneous ignition (8%).

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REFERENCES

[1] IMO, Sub-committee on ship systems and equipment (SSE 6), 4–8 Mar., 2019. https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/SSE-6th-session.aspx. Accessed on: 13 Jul. 2022.

[2] LASH FIRE, Deliverable D04.1: Review of accident causes and hazard identification report, May 2020. https://lashfire.eu/. Accessed on: 13 Jul. 2022.

[3] Wikman, J., Evegren, F., Rahm, M., Leroux, J., Breuillard, A., Kjellberg, M., Gustin, L. & Efraimsson, F., Study investigating cost effective measures for reducing the risk from fires on ro-ro passenger ships (FIRESAFE). EMSA, 2016.

[4] LASH FIRE, Deliverable D08.1: Definition and parametrization of critical fire hazards, classification of cargoes, transport units, engines, fuels and vessels and identification methodologies, June 2021. https://lashfire.eu/. Accessed on: 13 Jul. 2022.
[5] Correspondence Group on Casualty Analysis, Casualty statistics and investigation: Report of the Correspondence Group on Casualty Analysis. IMO, Sub-Committee of Flag State Implementation, 2012.
[6] GISIS, Home page. https://webaccounts.imo.org/. Accessed on: 22 Jun. 2020.
[7] LASH FIRE, Home page, 2022. https://lashfire.eu/. Accessed on: 13 Jul. 2022.
[8] ForeSea, Home page. https://foresea.org/. Accessed on: 22 Jun. 2022.
[9] Comisión Permanente de Investigación de Accidentes e Incidentes Marítimos, Investigaciones realizadas por la CIAIM, 2020. https://www.mitma.gob.es/organos-colegiados/ciaim. Accessed on: 20 Apr. 2022.
[10] Hellenic Bureau for Marine Casualties Investigation, Investigation reports, 2020. http://www.hbmci.gov.gr/indexEng.htm. Accessed on: 20 Apr. 2022.
[11] Ministry for Transport, Infrastructure and Capital Projects, Maritime Transport, Maritime Security, 2020. https://www.transport.gov.mt/maritime-40. Accessed on: 20 Apr. 2022.
[12] European Marine Casualty Information Platform. https://portal.emsa.europa.eu/web/emcip. Accessed on: 20 Apr. 2022.
[13] Gehandler, J., Karlsson, P. & Vylund, L., Risks associated with alternative fuels in road tunnels and underground garages, 2017. http://urn.kb.se/resolve?urn=urn:nbn:se:ri:diva-29101.
[14] Härdle, W.K. & Simar, L., *Multivariate Statistical Analysis*, 4th ed., 2015. DOI: 10.1007/978-3-662-45171-7.
[15] Fernandez, S. de la F., Análisis de Correspondencias Santiago de la Fuente Fernández, Fac. Ciencias Económicas y Empresariales, pp. 58–59, 2011. https://www.fuenterrebollo.com/Economicas/ECONOMETRIA/REDUCIR-DIMENSION/CORRESPONDENCIAS/correspondencias.pdf.
[16] Iyer, R.R., Sharma, M. & Saradhi, V., A correspondence analysis framework for author-conference recommendations, pp. 1–49, 2020. http://arxiv.org/abs/2001.02669.