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STATISTICAL AND AI MODELING OF UK AND FRANCE ELEVATOR ACCIDENTS AND THEIR VIOLATING SAFETY RULES

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This study presents a statistical analysis applying different statistical techniques, including trained Bayesian Networks an artificial intelligence (AI) method, to explore datasets of lift accidents involving safety rules for two countries: UK and France. The study concerns six years data for both countries and covers almost all elevator accidents taken place during private and professional uses; 218 cases for UK and 205 cases for France. The relevant time interval for U.K. is 6th January 2006 to 29th December 2012, while for France data concern the period of 18th February 2003 to 17th December 2009. The major aim of the study is to exhibit and demonstrate that for accident datasets, at least for similar datasets, multiple statistical methods have to be applied in order to extract reliable information, i.e. investigate interactions among factors and therefore help to develop prevention measures. Three statistical models were built to derive associations between factors concerning violation of rules related to the installation and maintenance of elevators, passengers' safety rules, risks and unforeseen circumstances. Associations between severity of injury and categories of gender or age of injured people have been found. Furthermore, specific influences between severity of injury and categories of type of rules or of type of accident have been identified. The obtained results will contribute to the design of efficient methods to avoid future accidents in both countries.

Keywords: elevators, accident prevention, data analysis, ordinal regression, generalized linear model, bayesian networks, mutual information, supervised learning

1 INTRODUCTION

Vertical transportation plays a crucial part in the building industry, bringing major improvements in urban areas. In the context of smart cities, continuous improvement of vertical transportation is considered to be of great interest across different directions i.e., higher carrying capacity, reduction of energy or of passengers waiting time [1],[2],[3],[4],[5]. It is worth noting that improper use of this technology may lead to a temporary malfunction or severe accidents and, consequently, cause injuries in people [6],[7].

Safety rules are of increasing necessity regarding vertical transformation devices. An extensive amount of research on accidents has been done regarding cranes [8],[9] and escalators [10],[11]. More work needs to be done regarding elevator accidents; to study in particular causes and effects [6],[7],[12],[13]. The general pattern is that most elevator accidents are not reported due to various reasons with most dominant the absence of responsible to keep data, state office. Therefore, data related to this, on certain occasions, are not being complete or representative. Analysis of existing elevator accidents could have a vital role in developing an efficient accident prevention policy in Safety science. As an example, according to official data [14], deaths and injuries related to the use of elevators happen during installation or repair works. Elevator-related deaths, which happen due to falls, take up more than half of all cases [15]. Given these accidents, it is clear that the understanding of them is insufficient and needs further investigations.

EU has published the standard EN 81-80:2020 document, (UNE EN 81-80:2020 Safety rules for the construction and installation of lifts -Existing lifts- Part 80: Rules for the improvement of safety of existing passenger and goods passenger lifts), identifying seventy-four dangerous situations and relevant guidelines on preventing various accidents related to elevator fatalities [3]. This document aims to increase the awareness of health and safety rules among people, especially workers and technicians. Nevertheless, the cases, where the ignorance and violation of these rules take place, have been increased in recent years. It is obvious that a statistical analysis investigating causes of lifts accidents across Europe is very important. Recent surveys reveal that due to fatal lifts accidents, 160,000 human losses occurred around the globe with 4.6% of them concerning France and 2.8% of Great Britain. This statistical data considers different causes of deaths from which it is hard to determine accidents related to falls from elevator shafts or the mechanical malfunction of elevators. As it has been noted previously, research works as well as official dataset related to elevator accidents are limited; the overview on occupational safety measures in each country may clarify the prevention of accidents.

The aim of this work paper is to demonstrate that a meaningful statistical analysis concerning accidents and causes of accidents demands the integration of several different statistical techniques, including trained Bayesian Networks (BNs). The study concerns datasets of accidents from two European countries for six years data. All data used for the present study can be found in “Zarikas, Vasilios (2021), “lifts accidents UK and France”, Mendeley Data, V1, doi: 10.17632/spvftz7gbs.1”, [16]. This work is an extension of [13]. In [13] only data regarding France were considered. In this work a more complete study is presented including more data from UK and France. The target is to exhibit that for such accident datasets, multiple statistical methods have to be applied in order to extract reliable information concerning the violated safety rules, the causes and the severity of the accident. It is necessary to estimate correlations, associations, and “causal” influences with the help of the mutual information quantity. This is the only way to investigate interactions among factors and therefore help to develop prevention measures. Three statistical models were built to derive all possible interactions between factors concerning violation of rules related to the installation and maintenance of elevators, passengers’ safety rules, risks and unforeseen circumstances.

Three statistical models are introduced: a generalized linear, an ordinal regression, and a Bayesian network model constructed by supervised learning. Statistical factors that we consider concern various characteristics of the accident and several safety rules/regulations that have been violated, described in the Methodology section.

The first model searches for correlations/associations of one dependent variable and many independent factors. The severity of the accident concerning the result of injuries is selected as the dependent variable and all the other continuous, discrete and categorical factors are considered as predictors. However, only the predictors with the greatest contribution to the variance matrix were finally used for the model.

The second model is a generalized linear model. The purpose was to search associations between the violation of safety rules and the characteristics of the accident. The sum of injured people was chosen as a dependent variable, while Gender, age, accident type, rules and faults, severity of injury were explanatory variables or factors. Year and month of the accident were chosen as covariates for this model.

The third model, is a Bayesian Network (BN) with its structure, topology and nodes specified by data with unsupervised learning. BN is an artificial intelligence method with the help of it, it is possible to build an expert model. It helps to discover causal relationships among informational nodes. Supervised learning algorithm was used to determine influences with respect to a target variable, the severity of injury.

2 ACCIDENTS ANALYSIS

The statistical methods for the analysis of crucial factors related to elevator accidents should be studied to understand which random variables affect mostly the frequency of occurrence of such unexpected situations and which associations between causes and accident characteristics often influence the severity of accidents [17]. This knowledge will guide the measures that should be taken into account to prevent the accident from happening. The understanding of causes about elevator accidents requires work described by these two techniques [3]:

- A direct approach whereas accident causes are identified by expert judgment (i.e., in terms of registered accidents and elevator users);
- A statistical approach whereas accident causes are described as risk factors.

Further, for a statistical approach, there are several statistical methods that can be utilized in order to extract meaningful inferences. There is various frequentist type of techniques as well as Bayesian methods. For a causal analysis of accidents Bayesian Networks seem more adequate especially when their structure is determined with the help of mutual information, a mathematical quantity coming from information theory.

It can also be noted that applying such an analysis on elevator accidents could be helpful to get “a first look” at data, but further analysis should be proceeded with validation and reliability [3],[18].

It is worth mentioning that severity of accidents or injuries is a dependent variable studied in several current studies [19],[20],[21]. It often consists of only three states (i.e. low, medium and high). At the work of [19], it is noted that a human expert determines which factors affect the severity of an accident. For example, young drivers may be associated, subject to their driving experience or their specific behavior, to car accidents. Further, accident severity was denoted to be a dependent variable, whereas several factors were termed to be independent (i.e. road type, external environment, driver characteristics and accident type). Binary logistic regression model was applied, assuming there were no multicollinearity issues between variables and that data was binary in nature. Only dichotomous variables were used (i.e. only two levels: 0 – with low frequency of occurrence and 1 – with high frequency of occurrence). It has been found that gender has a very low effect on accident severity on car accidents. The same method has been applied in traffic analysis involving the use of an ordered probit model with a log-likelihood function, where explanatory variables were considered to be homogeneous [20]. Alternatively, generalized ordered logit model was applied to data, where coefficients of the variable varied among different categories of the presented variable. However, it is important to note that this type of analysis could be, at some point, be subjective based on the information provided by an expert.

Regarding accidents’ analysis directly connected to lifts, it is possible to identify possible associations between accident type, severity of accident, date of event and location. These associations can be easily explored using conventional frequentist statistics for correlation and variance analysis. For example, in [22], frequentist statistics was used to study any inconsistencies in data and to identify relationships between factors. Finally, ANOVA analysis has been carried out to find out the relationships between categorical variables, which could be useful for variables with more than two categories. It can also be noted that ideally collected data on accidents' occurrence should be uniformly distributed. Perhaps factors affect the correlations between variables in a very different way, if adding or subtracting some of them. Chi-square test and Goodness-of-fit are also relevant for testing the strength of the relationships between variables [23],[24].

The application of the above-discussed techniques is very informative. Regarding the causal analysis, however, an expert judgment is needed to help to identify the causes of the accidents. Then regression methods could be applied to state the cause, which highly influences the accident occurrence, whereas the least ones will be excluded from the analysis [25].

Bayesian networks have already successfully applied in many disciplines i.e., medicine, environment problems, risk management/safety and reliability [2],[26],[27],[28],[29],[30],[31],[32]. Bayesian networks together with utility theory can also be used for finding optimal policies in many different fields [22],[26],[33],[34],[35],[36],[37],[38]. Bayesian networks and information theory methods which belong to AI techniques, is a powerful tool built for the exploration of causal relationships. A first study regarding these accidents can be seen in [13].

The structure and the topology of modern BNs are identified from unsupervised and supervised learning. In terms of the unsupervised learning technique, it can be applied to data with no target variable to initially understand the relationships between variables. Furthermore, unsupervised learning can be used with a known target variable to see the “causal” among a target variable and other predictors.

In traditional statistical analysis one typical technique that is useful for accidents analysis is Pearson’s correlation. It plays an important role to evaluate the interactions between factors “α_i”.

$$P(\alpha_i, \alpha_j) = cov(\alpha_i, \alpha_j)/\sqrt{var(\alpha_i) \cdot var(\alpha_j)} \quad (1)$$

The formula expressing the strength of correlation between variables:

$$r_{XY} = \left(\sum_{i=1}^{n}(X_i - \bar{X})^2\right)^{-1/2}\left(\sum_{i=1}^{n}(X_i - \bar{X})^2\right)^{-1/2}\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y}) \quad (2)$$

where, X and Y are two variables correlation of which is required to find.

On the other hand, a supervised learning procedure for determining the topology of the Bayesian Network can be done by creating a Naive model and running the structural analysis to check its precision or using the Augmented Naive model (important for small datasets) [39]. The Naive model uses the famous Bayes formula to identify joint probabilities not only between dependent variables and one target variable but also between several “child” nodes.

$$P(A|B) = P(B|A) \cdot \frac{P(A)}{P(B)} \quad (3)$$

The strength of the arcs in the Bayesian Network (BN) are evaluated using the mutual information. The Mutual Information I between variables X and Y is defined by:

$$I(X,Y) = H(X) - H(X|Y) \quad (4)$$

or

$$I(X,Y) = \sum_{y \in Y} p(y) \sum_{x \in X} p(x|y) \; \log_2 \frac{p(x|y)}{p(x)} \quad (5)$$

The learning of the BN would be different if we were to choose the Pearson’s Correlation as the main metric. The main motivation of using Mutual Information is that it can be estimated between numerical and categorical factors, without any variable transformation. For example, we can easily compute the Mutual Information, between the Age and Accident type. Thus, there is a central role of entropy and Mutual Information, for BN machine learning and BN network analysis.

The present paper focuses on studying causes for the occurrence of serious elevator accidents. One main target of the paper is to make connections with the type of violating rules. We will take as a reference list the safety rules reported in EN 81-80:2020 document. The Dataset from both countries UK and France will be used to find explanatory statistical factors that affect severity of injury and other accident characteristics.

In section 3, the data collection method will be presented for both France and Great Britain. A methodology on implemented causal analysis will be also discussed. Three statistical models will be introduced: generalized linear, ordinal regression, and Bayesian prediction models. In section 4, results will be presented and briefly discussed. In section 5 a discussion of results and conclusions will be given and compared. Finally, based on the statistical analysis, several crucial recommendations will be presented about the prevention of such accidents related to their severity.

3 METHODOLOGY

The collection and filtering of meaningful data concerning elevator accidents proved to be very time consuming. We have utilized several databases from health/safety organizations and ministries (e.g. HSE, NHS, RIDDOR, AMELI, etc.). An official data request was completed and sent to each organization. However, it was found that, in some cases, data consisted of just an overall statistic for fatal and non-fatal injuries without details. As a result, some governmental datasets unfortunately were not useful. Main obstacles in our data search included lack of information about the severity of an injury or the accident type, incomplete and heterogeneous coverage of accidents etc.

After a first check, in order to conduct a meaningful data analysis and to overcome these problems, we studied datasets from European sources [40]. We have focused on the UK governmental data and European Open Data. It has already been proven that these datasets are consistent and have already been used for some research works [23],[41],[42]. For the UK, the time frame for elevator accidents covered from 6th January 2006 to 29th December, 2012, whereas for France it was the period of 18th February, 2003 to 17th December, 2009. The present analysis process and analyses data of a time period of 6 most recent years for both countries. Data regarding earlier years was incomplete and partially unreliable.

Considering the limited number of complete datasets, the present data study utilizes a fair number of cases; more than 200 accidents. We managed to gather information for each case about date and places of an accident (e.g. 28 cities for the UK and France), accident types per injured person and violated safety rules. The sample size is similar to other studies of suchlike statistical works [3],[22].

The parameters/factors per accident are, Year and month of accident, Location, Total number of injured people, Age and gender of an injured person, Type of Accident, Fault type, Grade about the severity of injury and rules/regulations that have been violated [43],[44]. Their states are: **Date** [year-month], **Place** [A province where the accident happened, for each country, 28 cities have been included], **Sum of injured** [An overall number of injured people], **Gender** [Female: F, Male: M, Unknown: U], **Age** [Young aged (1-12): C12, Teenagers (13-18): Ad18, Middle aged (19-59): A59, Seniors (aged) (60-85): SA60, Unknown age: UNV], **Accident type** [Professional: PRO, Private: PRI], **Fault type** [Categories of elevators: Doors, Electrocution, Falls, Fire, Floor, General, Landing, Machinery, Power, Repair, Speeding, Sudden stops, Vandalism], **Severity of injury**, [Light: 1 or A, Heavy: 2 or B, Fatal: 3 or C, Light/Heavy:4 or AB, Light/Fatal: 5 or AC, Heavy/Fatal: 6 or BC], **Safety Rules** [Light: 1 or A, Heavy: 2 or B, Fatal: 3 or C, Light/Heavy:4 or AB, Light/Fatal: 5 or AC, Heavy/Fatal: 6 or BC]. Furthermore, the description of violated rules with the use of certain codes, is presented in Appendix, [43],[44]. It is also worth noting that most collected from databases factors regarding the UK and France are similar, which allows comparisons and explains the motivation of focusing on these two countries.

We have explained that the study of associations/correlations and causal connections for the case of accidents analysis is crucial. We have to extract from data which factors related to the violating rules are most influential to the severity of the accident. This has to be done for both professional and private uses and for each country. Three models have been determined for this task. The software packages used are SPSS and BayesiaLab. Model A is an ordinal regression model was applied, Model B is a generalized linear model and Model C is a Bayesian network model constructed with supervised learning. As always, a descriptive statistic (frequency and crosstabs tables) provides the first summary of the dataset [45] concerning the distributions. The significance level should be less than 0.05 throughout this paper.

The first method of statistical analysis, model A, searches for correlations/associations of one dependent variable and many independent factors. The severity of the accident concerning the result of injuries was selected as the dependent variable. All the other continuous discrete and categorical factors were considered initially as predictors. Only the predictors with the greatest contribution to the variance matrix were kept, running a loop for the regression model. The link function that was chosen and tested using log-log or Cauchit or even logit. The final choice of the link function for both countries will be reported in the dedicated for each country sections. The evaluation of the final model includes chi-square statistics (for estimating how strong are relationships between factors [46]) and a test if the presented model outperforms the intercept model.

In addition, pseudo R-squared statistics calculating Cox&Snell, Nagelkerke and McFadden have been done and finally the determination of the parameters were found for the relevant significant dependent variables. The particular results of ordinal regression model for each country are shown in section 4.

For model B, a generalized linear model was constructed for the data, fitting the Poisson regression. A generalized linear model is an extended linear model, which is useful to define non-normal responses [47]. The purpose was to investigate the associations between the violation of safety rules and the characteristics of the accident. The sum of injured was chosen as a dependent variable, which, in this case, is a count data in nature. Gender, age, accident type, rules and faults, severity of injury were explanatory variables or factors. Year and month of the accident were chosen as covariates for this model. The Poisson loglinear function was applied to the model with low frequencies. First, the goodness-of-fit was calculated based on Pearson's statistics by the sum of squares of observations from the model [48]. Then omnibus test was performed to see if the final model outperforms the intercept-only model. This test is a likelihood-ratio chi-square test of the current model versus the null (in this case, intercept) model. Next, the test of model effects was also performed to investigate the effect of terms presented to the current model. For this, the significance level should be no more than 0.05. Finally, parameter estimates have also been calculated to see if association between variables was positive or negative. Details on the interpretation of results will be described in section 4.

Model C, is an expert model based in one BN. The structure, topology and nodes can be specified from data with unsupervised learning. The advantage of using a BN is that it is a knowledge representation scheme, and it reveals the directions of influences. It helps to understand causal relationships among informational nodes. The informational nodes are all types of variables deterministic or probabilistic continuous or categorical. In the case of continuous variables these should be discretized.

In our case of course we focus on the influences with respect to the severity of the injury. That's why we run supervised learning algorithms with target variable the severity of injury.

The discretization algorithm that was selected is the "Tree" one. Next. The mutual information quantity is calculated for all interactions of variables to find the direction of influence as well as the strength of it. The learning algorithms in use were Naive and Augmented Naive ones. To further improve accuracy, precision and reliability (recall/specificity) a structural coefficient analysis was performed.

The final results for each country will be presented in next section.

Overall, models A, B and C were determined for each country. They reveal differences in associations between explanatory factors. Considering the presentation of the obtained tests and calculations from SPSS and BayesiaLab, it is worth noting that only few selected significant tables and figures have been included in the present work from the big number of derived ones will be presented.

4 RESULTS

4.1 Statistical outcomes regarding elevator accidents in France

The dataset concerning accidents in France consists of 205 cases. Some first statistical inferences regarding this set of data have been presented in [13]. In this work we run again the statistical models with a more optimal selection of various parameters. in a more complete way and refined results are presented.

First, descriptive statistics have been run to understand the distributions. Furthermore, crosstabs analysis to spot possible associations between variables (for further testing consequently with the appropriate for each pair or group of factors method). In summary, the most important inferences are (the reported differences have been checked to be statistically significant):

- Without performing any normalization or calibration most accidents occurred in 2007 and 2008 with more accidents taking place in January and in June.
- More elevator accidents per population happened in Dunkirk, Angres, Marseille and Toulouse.
- The number of injured persons is gender sensitive. More women (~10% more) have been reported as injured.
- Regarding the accident distribution per age category, the largest proportion is this of adults with ages from 20 to 59 with 41%. However, it is worth mentioning that there was a 20% of injured persons with unknown age.
- Injuries concerning plain users are about 54% while professional users 46%.
- Regarding the states of the severity of injuries in the dataset we have 42% of fatal injuries which is the largest proportion compared to light or heavy injuries. This is due to the fact that there is a tendency some accidents with not serious injuries not to be reported at all.
- For the states of the fault types, floor leveling problems cover the 13% of the cases while door opening problems 11% and lift motion problems 11%.
- The important states of the violated rules categorical variable are the types of IRMM and IRMM/RHS.
- It was also shown that there are significant associations for the severity of injury being the dependent variable and gender, age, accident type, fault and rules type as independent variables. Based on this analysis, strong associations exist between the severity of injury with gender and age, and moderately correlated with accident type, rules and fault types.

Furthermore, as we have explained previously, we constructed two statistical models for making inferences. The statistical inferences from the construction of the two statistical models: A – an ordinal regression model and B – a generalized linear model are quite a lot. It is worth noting that only some selected results will be presented here.

Running appropriate algorithms that identify the independent variables that most contribute to the variance matrix of the dependent factor we found almost same results with [13]. The optimal model has the "severity of injury" as the dependent variable and "sum of injured persons" and "gender" and "age" as predictors. We have tried various link functions and the model remained the same and have passed the consistency tests (Nagelkerke's value and parallel lines test). For more details see [13].

Regarding model B, a generalized linear model has been performed using Poisson loglinear function for scale variables with count data. The best model was chosen to have as dependent variable the "sum of injured persons" and predictor factors such as "elevator faults", "severity of injury" and "rules violated", with covariates as "year" and "month".

Firstly, Goodness-of-Fit statistics has shown that data are consistent, where the over-dispersed model is not needed based on the findings. In order to find the model fitting information, the Omnibus test has been executed based on likelihood ratio chi-square, whereas the significance level is lower than 0.05. It proves that our fitted model outperforms the intercept-only model.

It is shown that fault types, severity of injury and violated safety rules have strong associations with the sum of injured people. Finally, we have calculated the parameter estimates for each predictor variable in regards with the dependent variable. Regarding the severity of injury, [SOI.cat = 2] and [SOI.cat = 3] are in the higher association regarding the sum of injured with respect to the reference category [SOI.cat = 7] with negative associations. As for fault categories, [Fault.category = Doors], [Fault.category = Landing], [Fault.category = Fire] are in the higher position with respect to the reference category [Fault.category = Vandalism], resulting in positive associations with the sum of injured people. The violation of safety rules take place mostly with categories [Rules.category = IRMM/STP], [Rules.category = IRMM/RHS] and [Rules.category = IRMM] in regards with the reference category [Rules.category = RHS], resulting in positive association with the dependent variable.

Overall, it is noticed that IRMM rules are, mostly, violated, where there are accidents statistically related to elevator faults such as linked to doors, floor landing or accidents with fire.

Model C, consists of a Bayesian network. The BN was constructed using appropriate learning algorithms with target variable the severity of accident. Initially unsupervised learning (without any target variable specified) was performed in order to understand the various interconnections and the causal influences. Several algorithms have been used Taboo, EQ and Maximum Spanning Tree. All of them they pretty much create the same BN. Calculating mutual information for two informational nodes A and B, we can predict quite safely the direction of the causal directions A→B or A←B. With unsupervised learning we can also understand what can be the target variable (the dependent variable) in an unbiased way. For the supervised learning we have chosen several different algorithms like Naive Bayes, Markov Blanket, and the augmented versions of them. The results are mostly in agreement with the findings in [13]. Supervised learning constructs literally an expert model that can predict probabilistically the target variable. The augmented Naive model outperformed and gave very accurate predictions. Table 1 summarizes these results. Fig. 1 illustrates the differences in building causal relationships between a target variable and predictors. The analysis, see Fig. 2, revealed that the target variable is most influenced by Age, Gender, Sum of injured and location.

Table 1. Network performance about France

Model	Naive with structural coefficient of 1	Augmented Naive with structural coefficient of 0.1
Overall Precision	86.8293%	95.1220%
Mean Precision	93.0098%	97.4771%
Overall Reliability	86.7843%	95.1296%
Mean Reliability	92.4860%	96.7967%
Overall Relative Gini Index	91.1203%	98.9249%
Mean Relative Gini Index	95.2681%	99.3890%
Overall Relative Lift Index	96.1551%	99.5718%
Mean Relative Lift Index	97.9070%	99.7768%
Overall ROC Index	95.5679%	99.4702%
Mean ROC Index	97.6655%	99.7259%
Overall Calibration Index	83.3532%	78.7967%
Mean Calibration Index	77.7412%	84.9008%
Overall Log-Loss	0.3357	0.1282
Mean Binary Log-Loss	0.1343	0.0513
R	0.9426	0.9652
R2	0.8886	0.9315

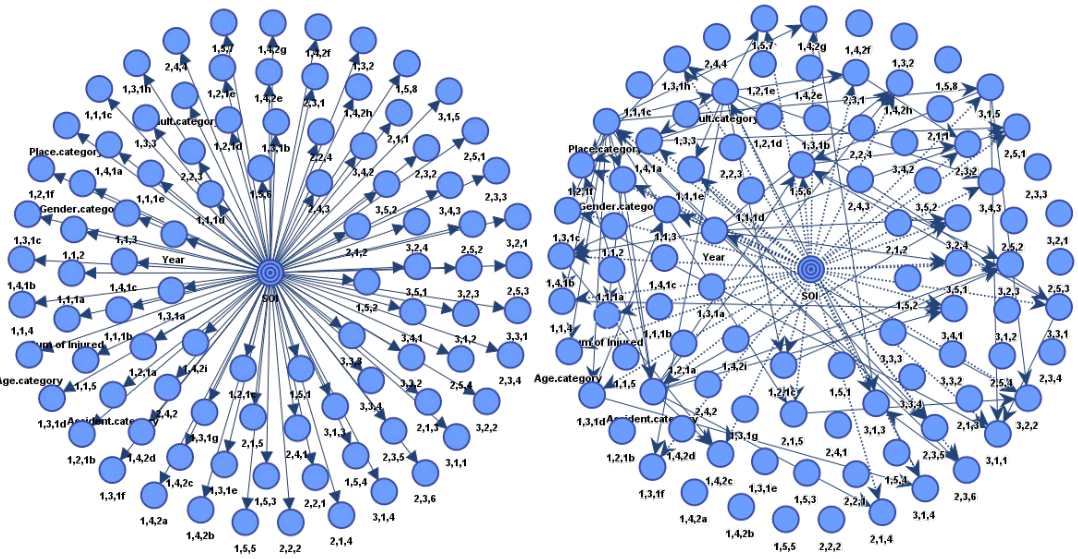

Fig. 1 Naïve & Augmented Naïve models for elevator accidents in France: a) SC = 1 and b) SC = 0.1

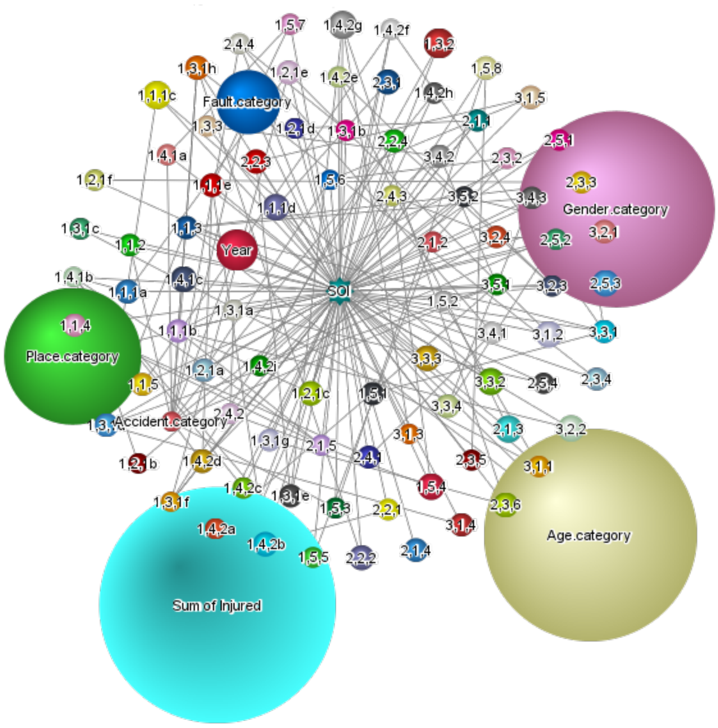

Fig. 2. Mutual information with the target node for elevator accidents in France

4.2 Statistical outcomes regarding elevator accidents in the UK

A descriptive statistic of accidents' data with 218 cases regarding the elevator accidents in the UK and crosstabs analysis were performed initially. Based on this information, the following preliminary conclusions can be extracted:

- More elevator accidents happened in 2007 and 2006;
- More elevator accidents took place at winter or spring, particularly in January (i.e. 11.5 percent) and in December, September and October with 11 percent each;
- Mostly men with 43.1 percent have been injured than women with 39.9 percent;
- Regarding the age group, people aged 19 to 59 (i.e. labeled as "A59") were injured or severely injured (i.e. 47.7 percent). The group of seniors labeled as "SA60" took the second place in injuries with 18.3 percent;
- As for the accident type, professional injuries have been more frequently occurred (i.e 53.7 percent) than the ones where the private use of elevators took place;
- The severity of injury labeled as "B" (i.e. heavy injuries) and "C" (i.e. fatal injuries) with approximately have been more frequent compared to others;
- Fault types such as the elevator problems related to landing with 13.3 percent and floor adjustments with 11.5 percent are prevalent;
- As for the violated rules, it is seen that people mostly violated the rules related to IRMM with 29.4 percent.
- Finally, significant associations appear to be between the severity of injury and categories of gender type and of age type.

Starting from model A, "severity of injury" has been chosen to be a dependent variable, ordinal in nature. Categorical variables such as "gender", "age" and "accident type" were included to the model as independent variables. The choice of the link function is complementary log-log. First, the Goodness-of-Fit model has shown that the included data to the model is consistent with the value, which is nearly equal to one. Furthermore, the model outperforms the intercept only model with $p<0.05$. In order to find the connection between the chosen link function and the final model, pseudo R-square has been evaluated. The result was that Nagelkerke's model is the best fit for model A with the value of 0.767. The test of parallel lines has also indicated that the final model rejects the null hypothesis.

Returning to parameter estimates, it is indicated that [SOI.cat = 2] is in the first regarding the contribution. Next, [SOI.cat = 3] has also a significant contribution with anegative association related to independent variables. The location shows that there exist no associations between the categories "age", "accident type" and the dependent variable "severity of injury", resulting in a significance level more than 0.05. For the gender state, [Gender.category = F] is most important concerning the severity of injury with respect to the reference category [Gender.category = U]. The state [Gender.category = M] is evaluated close to [Gender.category = F] in the lowest position of severity of injury with respect to the reference category [Gender.category = U].

Furthermore, a Generalized linear model has been built also for the case with elevator accidents in the UK using the Poisson loglinear function; this is model B for the UK data. "Sum of injured" was chosen as a dependent variable, whereas "accident type", "rules" and "faults" were considered to be independent. Covariates such as "year" and "month" proved to have negligible effect to the model. First step was to show if Goodness-of-Fit statistics indicates that the data is consistent and whether the over-dispersed model is needed or not. The final model was tested and outperforms the intercept only model, showing significance level $p<0.05$, based on likelihood ratio chi-square statistics.

Model B effects for several independent variables were evaluated. As the case, SOI.cat is in the higher explanatory variable regarding the relevance, whereas AccidentType and Rules.category also contribute and have somewhat less and both the same level of effect to the model. It is worth noting that Faults.category has a significance level, which is equal to 0.055, however its effect to the model is also included.

Finally, the parameter estimates of model B regarding the dependent variables are: [SOI.cat = 2] is located in the higher influential importance regarding the sum of injured with respect to the reference category [SOI.cat = 6]. [SOI.cat = 3] is situated in the lower position next to [SOI.cat = 2] with respect to the reference category [SOI.cat = 6]. Next, [AccidentType = PRI] has also a significance level lower than 0.05, and has strong associations in regards with the dependent variable with respect to the reference category [AccidentType = PRO]. As for violated rules, [Rules.category = RHS] has also statistically significant association with respect to the reference category [Rules.category = STP]. Finally for fault categories, [Fault.category = Repair] has strong associations with the dependent variable, with respect to the reference category [Fault.category = Vandalism]. Overall, it is noticed RHS rules are, mostly, violated, where accidents related to repair works take place.

For model C, Fig. 3 illustrates the differences in building causal relationships between a target variable and predictors. By running an Augmented Naive model new causal relationships have appeared between "Fault.category" and "Accident Type", "Year" and "1.5.3", "Accident Type" and the number of violated rules such as "1.1.4", "1.3.1d", "1.3.1h", "1.4.2d", "2.3.1", "2.3.3", "2.3.4", "3.1.5" and "3.4.2". For the network choice, Augmented Naive model has been chosen regarding its higher accuracy and precision.

In Table 2, the overall precision for the final model has increased from almost 85 percent by building Naive model to 97 percent running an Augmented Naive model using structural coefficient of 1/10. The total log-loss value is equal to 0.0820 with R of 0.9697, which indicates that the final model outperforms the previously presented Naive model.

After choosing Augmented Naive model for further analysis, mutual information regarding the target node has been evaluated. In Fig. 4, it is noticed that "Age.category" has higher contribution to the target node with the value of 0.6593. The next variables, which have higher effect on a target node are "Gender" and "Sum of Injured" with the value of more than 0.5. Common variables, which have higher contribution to the model are "Place" with value 0.2438 and "Fault.category" with value of 0.16. The contribution with values between 0.03 to 0.1 has predictors such as "Year", "3.3.3", "1.5.8", "1.2.1c" and "2.5.3".

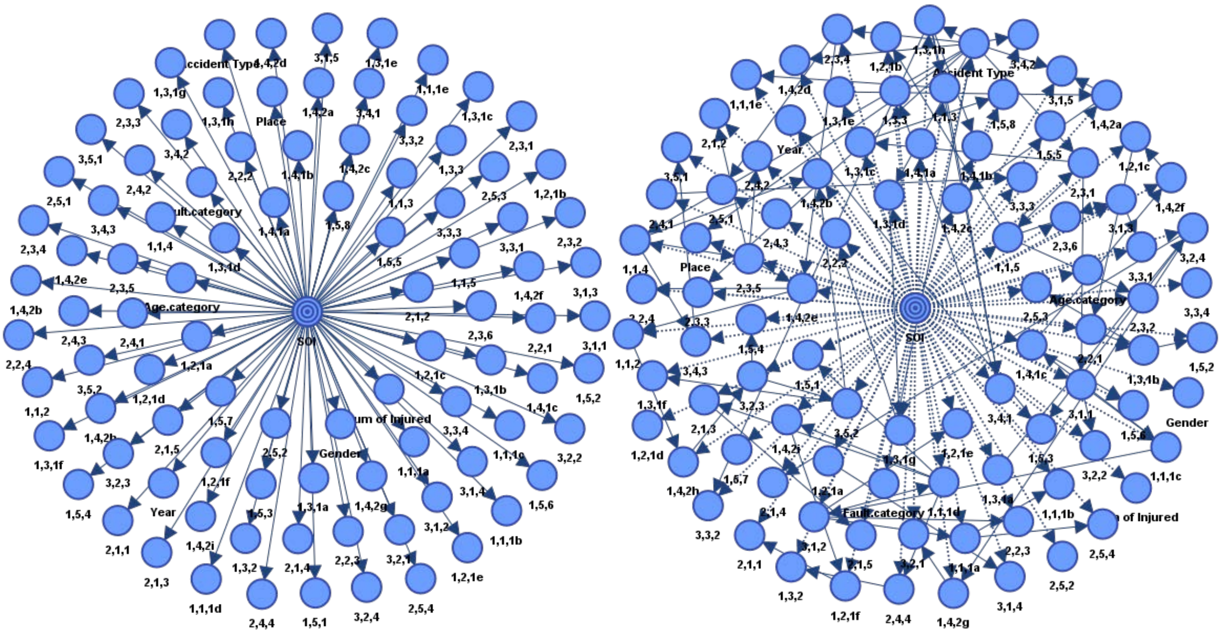

Fig. 3. Naive and Augmented Naive models for UK elevator accidents: a) SC = 1 and b) SC = 1/10

Table 2. Network performance about UK

Model:	Naive with structural coefficient =1	Augmented Naive, structural coefficient 1/10
Overall Precision	84.8624%	97.2477%
Mean Precision	92.7001%	98.6707%
Overall Reliability	84.8739%	97.2477%

Model:	Naive with structural coefficient =1	Augmented Naive, structural coefficient 1/10
Mean Reliability	92.6877%	98.6707%
Overall Relative Gini Index	88.0842%	99.2512%
Mean Relative Gini Index	94.1551%	99.5388%
Overall Relative Lift Index	95.1181%	99.7212%
Mean Relative Lift Index	97.6313%	99.8651%
Overall ROC Index	94.0491%	99.6326%
Mean ROC Index	97.1310%	99.8229%
Overall Calibration Index	81.3453%	81.1438%
Mean Calibration Index	79.0956%	90.9482%
Overall Log-Loss	0.3317	0.0820
Mean Binary Log-Loss	0.1327	0.0328
R	0.8595	0.9697
R2	0.7387	0.9403

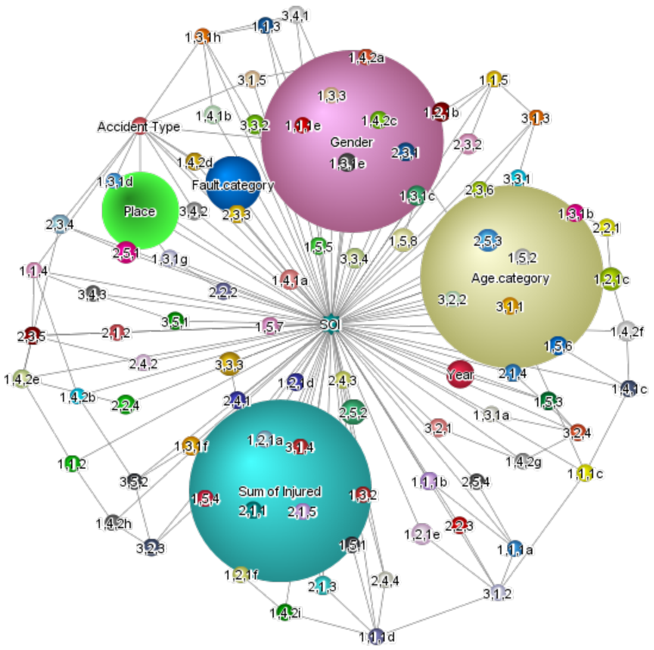

Fig. 4. Mutual information interactions with the severity of injury which is the target node for elevator accidents in the UK

5 DISCUSSION/SUMMARY

Based on the statistical analysis, the obtained results presented above for both countries (e.g. France and the UK) have brought some very important insights on the frequency of occurrence and unforeseen reasons of elevator accidents. Significant factors that influence the severity of injury have also been evaluated, whilst the violated rules and faulty types whereas these accidents take place have been identified. However, it is worth noting that the size of the datasets is not very big. This limitation was taken into account, and we believe using the three different models it was able to extract nontrivial information. Some noticeable results are reported in this section.

Concerning the gender and age group of injured people, in France, females had more injuries than males. This outcome contradicts with official data, which states than males had more injuries than females. It is explained by the fact that our current research work targets not only occupational injuries, but also includes domestic ones. Another important outcome is that a prevalent part of such injuries is due to several causes: problems with floor leveling, incorrectly opened elevator doors and lift speeding problems.

Regarding elevator accidents in the UK, male users were prone to be more injured than female users because of a maintenance and technical work that men mostly take. It is related to the violation of rules regarding the provision of safety equipment during the maintenance work or a mechanical failure of an elevator. Furthermore, professional injuries have a frequent occurrence compared to those of a “private” usage. Most accidents took place because of several problems related to elevator landing and floor leveling. As it can be seen from results, both countries had more fatal and heavy injuries than light injuries at a given time frame, and it is explained by the fact that the most part of reports concerning occupational and domestic injuries are not submitted by softly injured people.

One of the aims of the current research work was to investigate what factors affect the severity of injury. For this reason, two separate samples for each country were created to run an ordinal regression analysis. Results in France, show that the categories of gender and of age have a significant effect on severity of injury. As for the UK, it is shown that only the category of gender has a considerable effect on severity of injury.

Another question is whether categories of violated rules and faulty type affect the occurrence of such accidents with severe injuries. For this, generalized linear models were created to study the associations between these factors. In case of elevator accidents in France, some categories of severity of injury, violated rules and faulty type have a significant effect on the number of injured persons. More precisely, important violated safety rules concern installing, repairing, and elevator problems with door openings, landing and fire. As for generalized linear model created for UK database, categories of severity of injury, accident type and violated rules have a significant effect on the number of injured people. This model shows that violated rules related to risks and hazardous situations (RHS) are influential.
Finally, two Bayesian expert models for prediction were built with severity of injury as a target variable. Regarding elevator accidents in France, the prediction expert model shows the influences between severity of injury and categories of gender and age. The results agree with ordinal regression model results as previously discussed. Several safety rules also have high influences with severity of injury:

- "1.3.2" – Unauthorized people should not be allowed in the machine room.
- "1.1.1c"- Lift workers should be provided with necessary information (drawings, manuals, instructions, etc.);
- "1.4.2g" – Lift workers should be provided with protective equipment/instructions in the machine room, if the machinery is on working mode;
- As for the UK, significant influences exist between severity of injury and the category of gender, which agrees with previous results. Safety rules have been violated regarding:
- "1.2.1c" - The lift pit should be kept clean and dry to prevent any slipping hazard. Lift workers should be provided with instructions, if there is water in the lift pit;
- "1.5.8" - All installed lifting equipment provided in machinery spaces or pulley rooms should be used only within its safe working load;
- "2.5.3" - No lockable main switch. A person switches the lift on when another person is working on the lift. As a result, a lift worker could be injured (electric shock, burns, etc.);
- "3.3.3" – Passengers should pay attention to the floor indicators

According to these results, noticeable extracted information was derived by these three statistical models. Ordinal regression was chosen for the ordinal in nature severity of injury. Generalized linear model was structured to investigate the number of injured people as a dependent variable. Finally, two Bayesian expert models were designed after supervised learning to explore causal influences. As stated previously, in both regression and Bayesian models strong associations have been found. However, perhaps the most interesting outcome regarding the influence of types of violated rules was achieved with the Bayesian expert models.

The generated statistical inferences could be used from policy makers and stakeholders [49],[50], to determine a strategy that will reduce heavy and fatal accidents. As for future work, we aim to increase the range of collected datasets and apply the same technique to other countries.

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7 APPENDIX

Indexes of safety rules violated in each lift related accident.

- https://www.emsd.gov.hk/filemanager/en/content_826/Gdlns_LiftShaftWorks_V3%20(Renew).pdf Guidelines on Safety of Lift Shaft Works (Volume 3 – Throughout the Occupation Stage of Building). 2013. Construction Industry Council
- https://www.emsd.gov.hk/en/lifts_and_escalators_safety/publications/code_of_practice/ .Code of Practice for lift workers and escalator works. Electrical and Mechanical Service Department.

Here we have selected some relevant rules and guidelines from the list described in 1,2 relevant for our statistical study. These rules/guidelines have been enumerated for further consideration in the statistical process.

1. Installing, repairing, modernizing and maintaining lifts

1.1General Precautions

1.1.1 Lift Works are essential to keep lifts in safe working order. The Lift Contractor has the responsibility for ensuring the safety and health of Lift Workers carrying out the works and occupants / users of the building. To proper discharge this duty, the Lift Contractor should:

(a) maintain all fire safety measures in the occupied building to ensure the safety of the occupants at all times;

(b) provide adequate training and specific instructions to Lift Workers for them to carry out the works properly and in a safe manner;

(c) provide Lift Workers with all the necessary information, including relevant layout drawings, method statements, and corresponding manuals issued by the lift manufacturer

(d) ensure that necessary plant, equipment and tools are properly maintained and are available for immediate use;and

(e) ensure that an effective communication means is provided for Lift Workers during the works.

1.1.2 The Lift Contractor and workers in discharging his duty in lift shaft works should make reference to relevant legislation, codes of practice and guidelines. The conditions of lifts should be controlled and inspected in a timelymanner.

1.1.3 For the Lift Works and associated building works, in order to inhibit the spread of fire between floor compartments through the lift shaft and openings, fire separation integrity of the lift shaft should be maintained at alltimes

1.1.4 Use of volatile organic compounds (VOC) during Lift Works should be properly controlled. To avoid health hazards to Lift Workers, the Lift Contractor should ensure that adequate ventilation is provided and maintained at the workplace. In addition, the Lift Workers involved should be provided with suitable respiratory protective equipment and effective supervision should be taken to ensure that the equipment is used properly.

1.1.5 At the end of the installation process a certifier specialist should review the unit and provide a certification stating that the unit is safe for further handle. After modernization related parties should receive a certificate stating that an elevator is safe for further use. All lifts and escalators should be prevented from operations after the specifiedservice life (specified by the manufacturer in the elevator passport) has run out.

1.2 Work inside Lift Pit

1.2.1 The Lift Contractor should ensure the following safety measures in place before the commencement of work orduring execution of work, as appropriate, inside a lift pit:

(a) The stopping device of the lift should be suitably tested for its effectiveness. To test the functionality of the stopping device, the manufacturer’s manual should be followed;

(b) Adequate lighting and ventilation should be provided. Lighting for working in the lift pit should be switchedon when Lift Workers are working inside the lift pit;

(c) The lift pit should be kept clean and dry to prevent any slipping hazard. No Lift Worker or any other personis allowed to carry out works in a lift pit with standing water;

(d) The stopping device located at the lift pit should be activated immediately once inside the lift pit;

(e) When leaving the lift pit, the stopping device as well as the door blocking device should be reset / removed only if the safe situation is ascertained. It is also needed to ensure that blocking device is properlymaintained and in working condition

1.2.2 Any scaffolding used inside a lift pit should be of non-combustible type.

1.3 Work inside Lift Shaft

1.3.1 The Lift Contractor should ensure the implementation of the following safety measures before work or during execution of work, as appropriate, inside a lift shaft:

(a) The number of persons working inside a lift shaft at the same time should be kept to a minimum. A permit-to-work system should be put in place where simultaneous operation by workers of different trades is unavoidable;

(b) Suitable entrance protection should be provided for guarding of openings in lift shaft. Barriers with warning notices should be erected in front of the landing doors. Landing doors should not be allowed to remain openany longer than necessary;

(c) Safe means of access and egress should be provided as necessary. Fall preventive measures should also beprovided to protect Lift Workers working at height;

(d) The safe spaces / clearances under the lift car in the pit and safe headroom above the lift car at the car top ofits travel should be ascertained before entering the lift shaft;

(e) Any temporary works including scaffoldings, formworks, planking and strutting, etc. erected inside a lift shaft during maintenance or replacement works should be constructed of non-combustible materials;

(f) Working under a suspended load (e.g. a counterweight or a suspension rope under installation) inside the liftshaft should be avoided and adequate safety measures should be taken in place to prevent accidental fall, slipping or displacement etc.;

(g) When landing doors are required to remain open, a proper door blocking device should be fitted in place tomechanically hold the doors in the open position; and

(h) A lift should not be returned to normal operation after completion of work until it has been ascertained thatno persons, tools, etc. remain inside the lift shaft.

1.3.2 Unauthorised persons should be prevented from entering the machine room whilst Lift Workers are working within the lift shaft.

1.3.3 If a platform lift is used for the Lift Works, the design and construction should be suitable.

1.4 Work inside Lift Machine Room

1.4.1 The Lift Contractor should ensure the following safety measures are in place before and during execution ofwork, as appropriate, in lift machine room. Access to Lift Machine Room should be:

(a) A safe access to and egress from every place of work inside the machine room, such as proper stairs, should be provided and maintained;

(b) Where a fixed access ladder of 3 metres or more is installed, it should be fitted with a suitable fall arresting device or suitable safety hoops. The spacing between rungs of the hoops should be at intervals not exceeding 1 metre.

(c) Passageway should be unobstructed and the floor surfaces should be non-slippery. Adequate measures shouldbe taken to prevent any tripping hazards.

(d) Working Safety in Lift Machine Room

(e) All Lift Workers working within a machinery space or pulley room should abide by all relevant safety signs;

(f) All lift machine room door(s) should be locked at all times when unattended during the works to prevent intrusion by other persons;

(g) Adequate ventilation and lighting should be provided in the lift machine room;

(h) Working platforms at height should be guarded with suitable guard-rails and toe-boards to prevent fall;

(i) The lift should be rendered inoperative as far as practicable before any inspection, cleaning, oiling or lubrication of wire ropes and moving parts.

(j) All dangerous parts of the machine, the whole lift installation and machines nearby should be effectively guarded to prevent injury to Lift Workers carrying out the Lift Works. As far as practicable, guards with a viewing window should be fitted for ropes or pulleys inspection;

(k) No work should be carried out on machinery while it is in motion or which is capable of intermittent motion.If it

(l) is not practicable, the Lift Contractor should provide other protective measures to prevent Lift Workers from injury;

(m) Risk assessment for manual handling operation should be carried out. Suitable lifting equipment should be provided for raising, lowering or suspension of heavy machine parts, materials and equipment; and

(n) The floor of the machine room should be non-slippery and measures should be taken to prevent any tripping hazards.

1.5 Lifting Operation

1.5.1 The Lift Contractor should prepare a lifting plan to define the rigging method applied to each machine part, material and equipment to be hoisted for the Lift Works. Properly designed, installed and maintained lifting equipment should be provided for conveying machine parts, material and equipment.

1.5.2 Any lifting appliances and lifting gear (LALG) used in the operation should be properly constructed and securely supported. The LALG should be also properly and regularly maintained, inspected, tested and thoroughlyexamined.

1.5.3 The Lift Contractor should ensure that erection of the appliances, including the installation and dismantling of anchor bolts, are carried out safely by a competent Lift Worker.

1.5.4 The operator of a power-driven lifting appliance should be trained and competent to operate the appliance. Heshould be familiar with the lifting appliance he is using

1.5.5 Loads, including lift parts and materials, should be securely rigged and fastened in order to prevent any undesirable movement or falling when they are being raised or lowered.

1.5.6 Lifting gear should be properly used during the lifting operation. It should be protected from damage by sharp edges.

1.5.7 No Lift Workers should be allowed to stay or work below the suspended load inside the lift shaft during the lifting operation. If this is unavoidable, the Lift Contractor should provide and maintain a lift shaft platform to act asa separation formwork to protect the Lift Workers working below the platform.

1.5.8 All installed lifting equipment provided in machinery spaces or pulley rooms should be used only within its safe working load.

2. Risks, hazard/hazardous situations

2.1.1 **Drive system with bad stopping / levelling accuracy**. Bad levelling accuracy (a step between car and landingdoor) can make people trip and fall or worse, bang their head on the wall of the lobby or inside the lift. In case of a wheelchair user, getting into the lift, back first, this risk can kill by breaking the neck or the skull of the disabled person:

Risk reduction measures: new controllers, regulated drive-systems and relevelling devices, make sure that thelift self-corrects and is always at the right level. The stopping accuracy of the car shall be +/- 10 mm, a levelling accuracy of +/- 20 mm shall be maintained. If, during e.g. loading and unloading phases, the value of 20 mm is exceeded, it shall be corrected.

2.1.2 **Unsafe locking device of landing door.** The landing door (swing door) is closed but not properly locked, the person is opening the door. no car is standing behind the door, the person falls down the well and is seriously hurt orkilled.

Risk reduction measures: The best way to prevent this type of accident is to install an adequate locking device on each landing door at every floor.

2.1.3 **Inadequate length of car apron.** Rescuing trapped persons when a car is stopped above the landing. Theperson can fall down the well.

Risk reduction measures An apron is positioned under the car. In case of stoppage of the car between 2 floors, ifthe passengers try to escape, climbing down on the landing, it often happens that they actually lose balance at the last second and fall in the shaft if the car apron is not long enough. The height of the vertical portion of the apron shall be at least 0,75 m.

2.1.4 **No or inadequate protective devices on power operated doors.** The person is passing through the doors when the doors start closing. The automatic doors close fast and hard, hitting the full body length of the person entering or leaving the car. Fragile, old and disabled persons can have limbs or the hip broken by the shock or by thesubsequent fall.

Risk reduction measures: Power operated doors must have an adequate protective closing device, detecting thepresence of a body in the way and reopening after at most a light touch. Often for this purpose, sensitive light screens are installed.

2.1.5 **Large car area in relation to rated car load.** The lift is not used as intended, the car is overloaded with persons and/or load. The car slips away from the landing. Persons are sheared and crushed. Serious injuries. It occurs often that a user tries to put too much and too high a weight in a lift (pallet of paper, photocopying machine,furniture...) and falls to his death if the lift is not equipped with a load limiter and a brake strongly keeping the lift from travelling.

Risk reduction measures: To prevent an overloading of the car by persons, the available area of the car shall be limited. Furthemore a lift shall be fitted with a device to prevent normal starting, including re-levelling, in the eventof overload in the car

2.2.1 **Car without doors.** Goods in the car hit the sill or recesses on the wall and tip suddenly. A child enters the gap between the car sill and the wall. Users are crushed, suffer serious injury or death.

Risk reduction measures:Lifts must be equipped with car doors, protecting the users from contact with a movingsurface.

2.2.2 **No or inadequate emergency light in car.** In case of loss of power supply, a user does not always have a lightsource at hand in the lift. It is then difficult to find the right button to go up or down, or to call for assistance by pushing on the intercom button. Panic and claustrophobia can be the result.

Risk reduction measures: All lifts should be equipped with emergency lighting in case of power failure.

2.2.3 **No or inadequate safety gear and/or overspeed governor on electric lifts.** Overspeed down or free fall ofthe car, due to the suspension failure, breaking of traction sheave shaft, brake failure, etc. If the safety gear fails tofunction, the lift is in free fall and can cause serious or even fatal accidents.

Risk reduction measures: There must be a state-of-the-art safety gear and overspeed governor on all existing lifts,that brings the lift to a stop in case of free fall.

2.2.4 **No or inadequate protection against free fall, overspeed and creeping on hydraulic lifts + no shut-off valve + no or inadequate low-pressure device on hydraulic lifts.** The car leaves the landing with open door and creates a step between landing and cabin or moves away uncontrolled. Persons can fall in or out of the car as a consequence. There can be several causes: failure of suspension means, rupture of hydraulic piping, oil leakage, dirt impairing valve closing. note: if the car moves out of the door zone, the landing door closes automatically, so the big step disappears. Pipe rupture or leakage on hydraulic lifts can cause overspeed or “creeping” lifts, up or down. This surprises a person who is busy cleaning or passengers and creates dangerous situations if adequate safety devices arenot installed.

Risk reduction measures: A shut-off valve and a double safety combination of safety valves, safety gear and relevelling device must equip all lifts (Amendment 3 also mentions this possibility of uncontrolled movement and risk reduction measures). A low-pressure device avoids danger for passengers and equipment caused by the free fallof the car during emergency lowering (manual or electrical). Regular maintenance and inspection help guarantee the functioning of safety systems, while reducing deterioration.

2.3.1 **Inadequate glass in door.**If there is a glass panel in a lift landing door, it must be safety or armed glass, making it impossible for a person to break the glass by impact and to pass a limb or an object through the opening. Itcan lead to falling into the well, shearing of limbs, serious injury or even death.

Risk reduction measures:All lifts with a glass panel in landing doors must be equipped with safety glass.

2.3.2 **No or inadequate vandal resistance.** Vandals can for example burn buttons made of varieties of plastic, which are slightly coming out of the surface of the button plate, or smash and scratch the car doors and car wallsurfaces.

Risk reduction measures.All Lifts that must be vandal resistant. Plastic buttons sticking out should be avoided andreplaced with metal or other material buttons, flush with the surface of the plate. glass doors and car mirrors must bemade of toughened safety glass or equivalent

2.3.3 **No or limited accessibility for disabled persons.** Older lifts are often not disabled-friendly. A small element such as door width or distance/height of buttons on the wall, can make a lift simply inaccessible for a disabled person in a wheelchair. Other functions are often missing: sound announcements, Braille or readable button indications, good lighting conditions, and of course general access to the lift (steps). This is of course much worse inpublic buildings or buildings accessible to the public.

Risk reduction measures: All lifts must be constructed or adapted so that they are accessible to ALL. Good guidance can be found in appropriate safety regulations for each country.

2.3.4. **No or inadequate control functions in case of fire.** In case of fire and smoke detection, the lift must automatically go to the exit floor, open its doors and stay there. Firemen must have access to the building and a have a key when they arrive on site, that enables them to takecontrol of the lift. With that key, they can travel.

Risk reduction measures. All lifts must be equipped with safety functionalities, such as the automatic travel of thelift to the evacuation floor, and have a fireman key for access and control of the lift by the fire brigade in case of fire.

2.3.4 **Inadequate locking devices on access doors + unlocking of landing door without a special tool.** Non authorized persons are entering the pit/well, and are crushed by moving parts. The fact that vandals or thieves openaccess doors to the well in order to do harm or hide things in the lift shaft can be very dangerous for the users of thelift in the building. The car door can be absent when the doors open.

Risk reduction measures: In order to avoid vandals and thieves to fiddle with the key,the lock should be a triangular key,that is not available in shops and strongly restricts vandalism and opening of lift landing doors.

2.3.6. **No protection means against ascending car overspeed on traction drive lifts with counterweight.** Overspeed in up direction due to failure of traction sheave shaft, brake failure, failure of electrical system, etc.. The person in the car is injured when the car hits the roof of the well. The maintenance person is crushed on the car roof.If there is no protective means installed to avoid car overspeed in up direction, the lift may shoot up rapidly and crash against the ceiling of the shaft.

Risk reduction measures: All traction drive lifts should be equipped with the necessary protective means.

2.4.1 **Presence of harmful materials, such as asbestos in brake linings, well, etc...** The technicians or inspectors (and possibly users) are exposed to harmful materials, due to wear, ageing, repair or modernization work. Asbestosis particularly harmful today in the building as it was used as insulation on walls and in cavities. The mechanic caninadvertently drill into it and create dangerous dust, which can cause a fatal lung disease much later in time.

Risk reduction measures: The owner of the building has to eradicate asbestos and other materials from the building, and hire specialist teams that remove it completely or like here, put a special film over the asbestos covered surfaces with stickers indicating that there is asbestos behind the film. Existing asbestos brake lining mustbe replaced with asbestos free brakes.

2.4.2 **Insufficient protection against electric shock and/or marking of electrical equipment; missing notices.**

For workers, the electric distribution board can be old and the wiring dangerous to work on or even approach.

Risk reduction measures: All electrical connections and wiring should be state-of-the-art.

2.4.3 **No or inadequate lighting of the well or inadequate lighting in machine or pulley room.** The lift well is aworking area for technicians and inspectors and can be a dangerous space to work in if not correctly lit.

Risk reduction measures: The pulley/machine room and the shaft will be lit with a light that can be switched offwhen not needed.

2.4.4 **Insufficient safety spaces in headroom and pit.** Mechanics and lift inspectors can be crushed between thetop of the car and the shaft ceiling or in the pit, if there is not sufficient pit and head room to hold him/them in a standing , crouched or lying position.

Risk reduction measures: There should be enough room on top of the car and in the pit when the lift is in extreme positions (actual space or at least space created by other means). There should be a stop button on the car roof and inthe pit, including also an inspection box on the car roof.

2.5.1 **Inadequate vertical surface below landing door sills + unsafe pit access.** Pit access, pit walls and bottomcan be in a very bad condition, with litter filling the pit, oil or liquid residues, the absence of a ladder, risk of fall from height , no lighting, etc... and no communication.

Risk reduction measures: The pit shall be clean, dry, the walls in good condition, a ladder provided and anintercom button with microphone must be put in the pit, to allow a trapped mechanic to call and request help(portable phones may not work in pits, shafts and confined spaces in general).

2.5.2 **No alarm system in pit or on car roof.** A person is trapped or injured in the pit or on the car. If there is no alarm system in the pit or on the car roof, rescue and treatment of injury cannot reach the mechanic in time. It canlead to serious injury.

Risk reduction measures: Install adequate alarm system in the pit and on the car roof.

2.5.3 **No lockable main switch.** A person switches the lift on when another person is working on the lift. Result: the maintenance/ inspection person is sheared or crushed. Injury to users or workers can take place, for example electricshock or unintended car move that can harm the mechanic working in the well.

Risk reduction measures: The main switch must be lockable by the mechanic when he works on the lift.

2.5.4 **No or inadequate partition of counterweight/balancing weight travel path + no or inadequate pit screen for several lifts in the same well + no or inadequate balustrade on car.** The mechanic working in a shaft with multiple lifts can be hit by the car or a moving part of another lift than the one he is working on. He can also fall in the shaft if there is no balustrade, harness system and/or adequate partition.

Risk reduction measures: If there are two or more lifts in the same well, balustrade and partitions must be installed where necessary. The technician must be protected from falling by a balustrade.

3. Elevator Safety Tips For Passengers

1.1 When passenger approaches the elevator:

3.1.1 Know the destination. Push the UP or DOWN button for the direction you want to go.
3.1.2 Stand aside for exiting passengers.
3.1.3 Wait for the next car if the elevator is full.
3.1.4 Do not try to stop a closing door with anything including hands, feet, canes, etc. Wait for the next elevator.
3.1.5 Take the stairs if there is a fire in the building.

1.2 When passenger enters and leaves the elevator:

3.2.1 Watch the step, and enter and exit carefully.
3.2.2 Hold children and pets firmly. The parent must first take the baby in his arms, go into the elevator with him, andthen bring the stroller inside.
3.2.3 Stand clear of the doors, and keep clothes and carry-ons away from the opening.
3.2.4 Push and hold the Door Open button if doors need to be held open, or ask someone to push the button for you.

1.3 When riding on an elevator:

3.3.1 Stand back from the doors.
3.3.2 Hold onto the handrail if one is available.
3.3.3 Pay attention to the floor indicators.
3.3.4 If the doors do not open when the elevator stops, push the Door Open button.

1.4 What someone should do when an elevator stops between floors:

3.4.1 Utilize the alarm button and wait for assistance.
3.4.2 If a phone is available, follow instructions to summon help.
3.4.3 Remain patient. There is plenty of air and the interior of the elevator is designed for passenger safety.

1.5 What someone should NOT do when an elevator stops between floors:

3.5.1 Do not attempt to force open the doors.
3.5.2 Do not attempt to leave the elevator. The elevator hatch is designed for professional personnel who will provide assistance from the outside of the elevator cab.

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