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Chapter 4

Results

Contents

Results

"Actually, everything that can be known has a number; for it is impossible to grasp anything with the mind or to recognize it without this."

- Philolaus, C.470 - C.385 BC.

Chapter 4 is aimed at providing the results of this study in which the factors that affect controllability in safety events, as depicted in the main research question, are first revealed by means of statistical analyses. Chi-square analysis methods were employed to demonstrate significant differences between the dependent and independent variables and statistically significant results are discussed in the subsequent chapters. Aside from the controllability in safety events, factors that may indicate bias of safety investigation authorities towards the severity of adverse outcomes were analysed to provide the results for the first sub research question. Numerical data was subsequently analysed with Spearman's correlation coefficient to explore the associations between variables.

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In chapter 3, independent variables were selected to be analysed with respect to the controllability of safety events and/or length of safety investigation reports. First, the overall frequency distributions of the controllability taxonomy are discussed (Section 4.1). With reference to the general distribution of the dependent variables, the significant differences found among these variables and the independent variables are hereafter presented (Section 4.2). Furthermore, Section 4.3 indicates the results whether severity and its associated variables of safety events contribute to the length of safety investigation reports (Section 4.4). Other significant differences are found in the Spearman's rho correlation analysis and certain combinations of variables were analysed to support the exploration of bias towards more severe events (Section 4.5). Finally, chapter 4 will be closed by means of a summary to prepare for the subsequent chapters (Section 4.4).

4.1. Frequency analysis

The first analysis was aimed at providing a general direction of the following results, in which this data yields the overall distribution of these results. This study ultimately consisted of 318 cases from the 297 analysed reports among the five safety investigation authorities. Several instances in the analysis of individual safety investigation reports included more than one safety event, single events that depicted multiple aircraft or controllers or the combination thereof. Of all the analysed cases, 51.1% were considered controlled events, indicating a high rate of controllable occurrences. Neutral and uncontrolled events were depicted in practically equal amounts with 24.6% and 24.3% respectively.

Involved personnel in the development of controlled events resulted more often (57.6%) in alleviated outcomes, without violations or errors and/or without worsening the outcome due to human actions. This naturally means that 42.6% of the controlled events resulted in adverse outcomes.

In addition, the distribution of the severity classes for the controlled events with respect to the distribution of severity classes without considering its controllability demonstrated certain differences (Figure 5). Without considering the controlled accident class, highest severity class "A" was found most often (43.4%). Lesser severity classes "B" and "C" were found in 5.7% and 25.5% of all cases respectively. The least severe classes "D" and "E" were found in 19.8% and 5.7% of all cases respectively. However, when taking the controlled class into consideration, differences were found for the three least severe classes. Severity class "C" presented the largest shift from the total occurrence severity distribution (approximately 10% more in controlled events). Severity class "D" and "E", on the other hand, were less often considered for controlled events than the overall occurrence distribution (approximately 6% and 4% less in controlled events respectively).

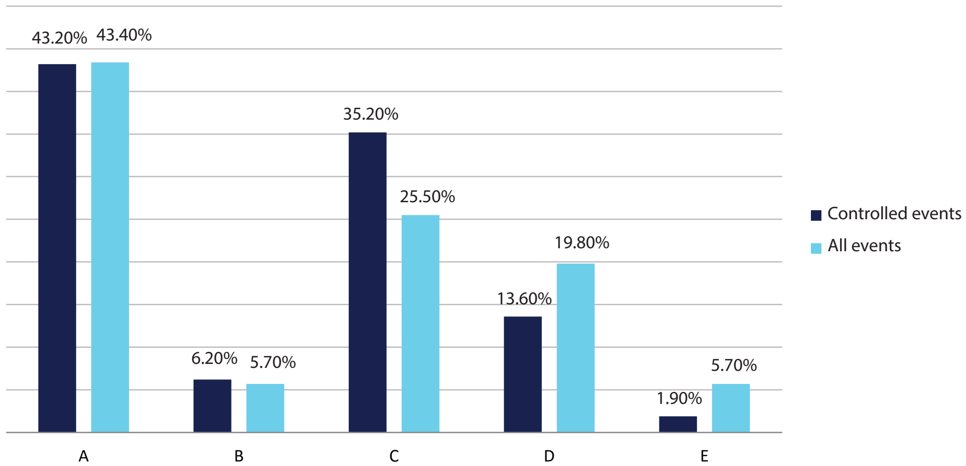

Figure 5. Overall occurrence severity classification with respect to the controlled events for the severity classification (N=318 for all events and N=162 for all controlled events).

4.2. Associated factors to safety event controllability

Table 6 shows the results of the Chi-square analysis of the independent variables with respect to the accident control classes and the human effectiveness in controlled occurrences. Both significant, as identified with bold type and underlined, and nonsignificant statistical results are presented in the table.

Similarly, Table 7 shows the results of the Chi-square test for the occurrence details and extent of safety investigation reports that demonstrate the significance of the respective distributions among the variables and accident control classes.

Table 6. Chi-square analysis results for the independent variables with respect to the accident control classes and outcome control attempt effectiveness.

Independent variables	**Accident control classes**		**Outcome control attempt**	
	Pearson Chi-Square value	Significance	Pearson Chi-Square value	Significance
Ordinary data				
Occurrence location - Continent	6.662	0.155	34.038	**0.000**
Occurrence location - Region	6.343	0.175	37.023	**0.000**
Occurrence location - Country	17.582	0.062	42.706	**0.000**
Operator nationality - Continent	6.900	0.141	29.868	**0.000**
Operator nationality - Region	9.862	0.043	26.863	**0.000**
Operator nationality - Country	16.701	0.081	41.301	**0.000**
Year of occurrence	5.010	0.543	1.663	0.645
Season of occurrence	3.292	0.771	6.624	0.085
Daytime at occurrence	4.543	0.604	2.638	0.451
Aircraft and flight specifics				
Age aircraft	13.809	**0.032**	1.310	0.727
Type aircraft	27.380	**0.000**	0.370	0.831
Weight class aircraft	28.167	**0.000**	0.068	0.794
Type of flight	23.356	**0.000**	0.000	0.989
Type of flight - Sub category	17.561	**0.000**	0.402	0.526
Flight phase at occurrence	12.505	**0.014**	5.606	0.061
Human performance				
Controller 1 - Age	1.227	0.541	1.826	0.177
Controller 1 - Type rating exp.**	9.663	**0.008**	0.197	0.657
Controller 1 - All time exp.	10.530	**0.005**	1.091	0.296
Controller 1 - Duty time	6.060	**0.048**	3.009	0.083
Controller 1 - Sleep period prior	0.219	0.896	0.014	1.000F
Controller 1 - Rest period prior	9.489	**0.009**	1.397	0.237
Controller 2 - Age	1.264	0.532	1.477	0.224
Controller 2 - Type rating exp.	3.472	0.176	0.010	0.921
Controller 2 - All time exp.	2.032	0.362	0.374	0.541
Controller 2 - Duty time	1.690	0.430	0.475	0.491
Controller 2 - Sleep period prior	0.608	0.706F***	2.143	0.333F
Controller 2 - Rest period prior	6.470	0.039	0.141	0.707
Fatigue as contributory factor	0.192	0.908	20.850	**0.000F**

Note. All results from the statistical Chi-square analysis are presented and do not all represent significant data. However, data not found significant in the test may comprise significant results.
* Bold and underline is significant P < 0.05
** Exp. Stand for Experience
*** Fisher's exact test's value

Table 7. Chi-square analysis results for occurrence related distributions with accident control classes

Variables	Accident control classes		Outcome control attempt	
	Pearson Chi-Square value	Significance	Pearson Chi-Square value	Significance
Occurrence details				
Occurrence category	73.080	**0.000**	36.409	**0.000**
Occurrence type	41.700	**0.000**	18.396	**0.000**
Occurrence severity	68.476	**0.000**	40.821	**0.000**
Associated fatalities	40.491	**0.000**	52.863	**0.000**
Associated serious injuries	3.902	0.142	11.725	**0.001**
Associated minor injuries	30.989	**0.000**	36.785	**0.000**
Extent investigation report				
Report - Total words	12.949	**0.044**	20.740	**0.000**
Report - Factual section	13.946	**0.030**	16,503	**0.001**
Report - Analysis section	11.011	0.088	26.001	**0.000**
Report - Conclusion section	10.357	0.110	19.196	**0.000**
Report - Recommendation section	12.459	**0.014**	12.982	**0.002**
Report - Quantity Recommendations	8.947	0.062	25.259	**0.000**

Note. All results from the statistical Chi-square analysis are presented and do not all represent significant data. However, data not found significant in the test may comprise significant results.
* Bold and underline is significant P < 0.05

4.2.1. Ordinary data results

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Location of occurrence and nationality

When taking into consideration the location of occurrence, only the outcome control attempts were found significant (Table 6 and 8). Australia and Europe were most involved in correctly executed control attempts (86.4% and 76.3% respectively). However, North America was recorded mostly for adverse outcomes (67.1%). These continental findings differed only marginally from the regional counterpart. More importantly, the country in which safety events occurred provided essential geographical details otherwise unknown from the regional and continental classifications. Australia, United Kingdom and the Netherlands were found most often in positive control attempts (86.4%, 85.2% and 72.4% respectively), while occurrences in the United States of America were mostly recorded for negative control attempts (79.1%).

The nationality of controllers demonstrated similar results as the location of occurrence. That is, Australians and Europeans were more involved in positive control attempts (86.4% and 78.2% respectively), while North Americans demonstrated higher frequencies of negatively controlled attempts (63.0%). Finally, the actual uncategorised nationality depicted strong results to the control attempt effectiveness. In all controlled events, Dutch and Australian controllers were recorded most often in positive control attempts (93.9% and 86.4% respectively), while Americans were found most frequently in negative control attempts (73.5%).

Table 8. Regional and continental distribution of control attempts for location of occurrence and nationality of the controller in terms of a percentage distribution. (N=318)

Independent variables	Outcome control attempt	
	Positive (%)	Negative (%)
Location of occurrence		
Continent		
Australia (N=37)	86.4	13.6
Europe (N=131)	76.3	23.7
North America (N=139)	32.9	67.1
Region		
Asia Pacific (N=42)	84.6	15.4
Europe (N=135)	77.4	22.6
Pan America (N=140)	32.3	67.6
Country		
Australia (N=22)	86.4	13.6
Canada (N=24)	54.2	45.8
Netherlands (N=29)	72.4	27.6
United Kingdom (N=27)	85.2	14.8
United States of America (N=43)	20.9	79.1
Other (N=18)	50.0	50.0
Nationality		
Continent		
Australia (N=36)	86.4	13.6
Europe (N=118)	78.2	21.8
North America (N=141)	27.0	63.0
Region		
Asia Pacific (N=45)	77.8	21.2
Europe (N=118)	77.4	22.6
Pan America (N=141)	32.3	67.6
Country		
Australia (N=22)	86.4	13.6
Canada (N=22)	59.1	40.9
Netherlands (N=15)	93.3	6.7
United Kingdom (N=29)	79.3	20.7
United States of America (N=49)	26.5	73.5
Other (N=23)	47.8	52.2

Temporal factors

The Chi-square analysis did not indicate any significant difference for each of the temporal factors across the accident control classes or the control attempt effectiveness of controlled events (See Table 6 and Appendix III). However, it can therefore be stated that no variations in time have been established in a time period of 25 years. Changes in season or time of day did also not affect the controllability or control attempt effectiveness.

4.2.2. Aircraft and flight specifics results

As shown in Table 6, the variables related to aircraft and flight details were only found significantly different for the accident controllability. Table 9 indicates the results of the Chi-square analysis for each of the affecting variables. It seems that aircraft with an age younger than seven years were less involved in uncontrolled events (16.9%), whilst aircraft older than 25 years were found more involved in uncontrolled events (32.9%). The type of aircraft also seems to affect the controllability, since rotary type aircraft were significantly more involved in uncontrolled events (43.2%). In contrast, jet type aircraft seemed to be less involved in uncontrolled events (15.1%). Weight classes of an aircraft were found to be in close association with the type of aircraft. Aircraft with a weight class less than 27.000 kilograms was more likely to be involved in uncontrolled events than aircraft with a higher weight class (33.9%).

The nature of flight operations was also found to be significantly different for the accident controllability. Commercial air traffic appeared with a very low frequency of uncontrolled events (18.5%), especially when compared to other flight types (42.9%). Passenger flights were also found to be less involved in uncontrolled events (17.7%). Events that occurred in ground phases were often associated with neutral events (37.4%) when compared to the remaining flight phases (16.8% for en-route and 21.4% for other flight phases). Both categories en-route and "other flight phases" presented similar results in which more than half of the accidents were controlled (56.8% and 55.0% respectively) while neutral accidents were depicted least (16.8% and 21.4% respectively).

Table 9. Aircraft specific and flight characteristic independent variables with respect to the accident control classes presented in terms of a percentage distribution.

Independent variables	Accident control classes		
	Controlled (%)	Neutral (%)	Uncontrolled (%)
Age aircraft			
0-6 (N=77)	45.5	37.7	16.9
7 – 14 (N=75)	56.0	20.0	24.0
15 – 24 (N=76)	51.3	22.4	26.3
Over 25 (N=74)	52.1	15.1	32.9
Type aircraft			
Jet (N=152)	50.0	34.9	15.1
Propeller (N=116)	54.3	16.4	29.3
Rotary (N=45)	47.7	9.1	43.2
Weight class aircraft			
0-27.000 (N=181)	50.6	15.6	33.9
Over 27.000 (N=134)	52.2	35.8	11.9
Type of flight			
Commercial Air Traffic (N=223)	54,5	27.0	18.5
Non-Commercial Air Traffic (N=84)	47.6	9.5	42.9
Type of flight - Sub category			
Passenger (N=164)	52.4	29.9	17.7
Non-Passenger (N=139)	52.9	13.0	34.1
Flight phase at occurrence			
En-Route (N=96)	56.8	16.8	26.3
Ground (N=91)	39.6	37.4	23.1
Other (N=131)	55.0	21.4	23.7

4.2.3. Human performance in safety events

Aircraft type experience

As summarised in Table 6, all cases that had more than one controller were not found statistically significant. All references associated with the controller that was involved in the development of safety events are hence, from this point on, intended for only the main controller (i.e. "Controller 1" in the referenced tables). The age of controllers did not seem to affect either the controllability or effectiveness of the control attempt. However, the experience was found to affect the accident control classes significantly (Figure 6). More experienced controllers were both more involved in controlled (59.8% for aircraft type experience and 58.6% for all type experience) and neutral (22.1% for aircraft type experience and 21.8% for all type experience) events than less experienced controllers. Differences were found most interesting in uncontrolled events, wherein more experienced controllers were substantially less involved (18.0% for aircraft type experience and 19.5% for all type experience).

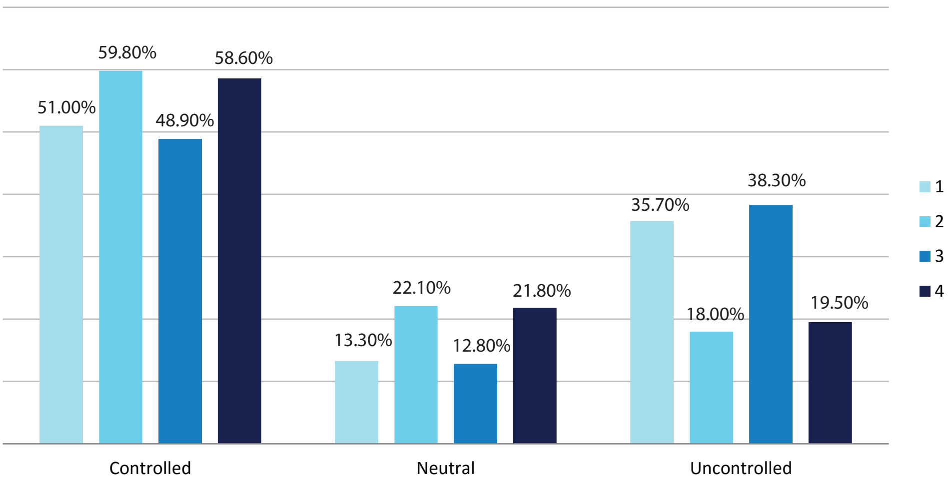

Figure 6. Experience of pilots as derived from the type specific and all type rating flight hours per the percentage distribution for the accident control classes.
Note. 1 indicates ≤1000 hours type rating; 2 indicates ≥1001 hours type rating; 3 indicates ≤5200 hours all type rating; 4 indicates ≥5201 hours all type rating. Type rating experience N=221, and all type rating experience N=228

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Time on duty

The distribution of accident control classes was found significantly different for the time on duty at the moment the respective event occurred (Table 6). Results show that longer duty time periods (i.e. more than 5 hours) are associated with less uncontrolled events (15.0%) (Figure 7). Longer duty periods are therefore more associated with neutral (21.7%) and controlled (63.3%) events.

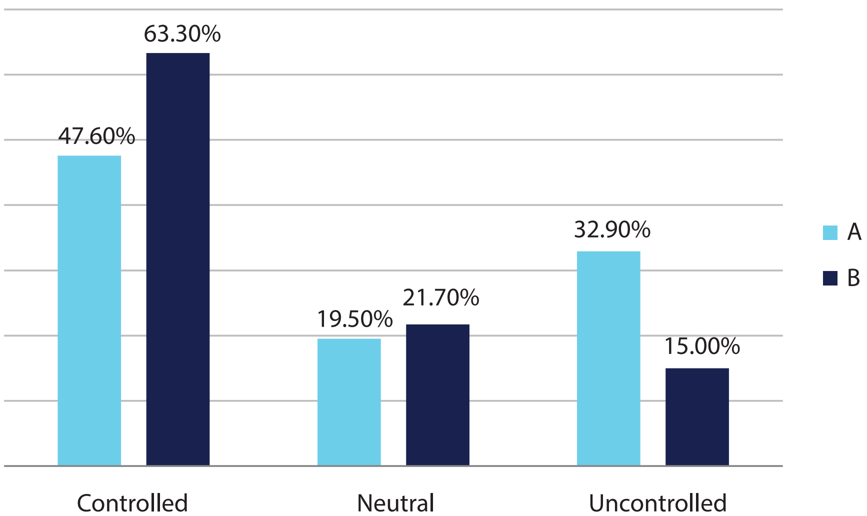

Figure 7. Duty time period with respect to the accident control classes in terms of a percentage distribution.(N=143). Note. "A" represents less than or equal to 5 hours of duty time; "B" represents more than 5 hours of duty time.

Rest period prior to duty

Controllers with rest periods of twenty hours or more were more involved in controlled events (71.4%) (Figure 8). In that regard, longer rest periods were also less involved in uncontrolled events (8.2%).

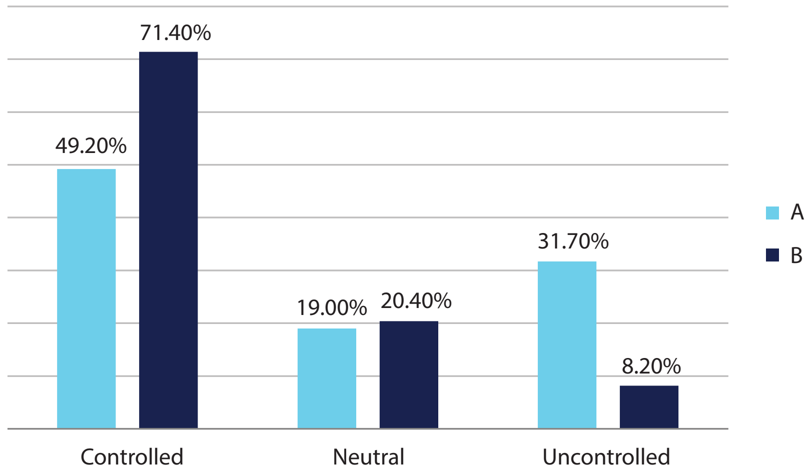

Figure 8. Rest period with respect to the accident control classes in terms of a percentage distribution. (N=112). Note: "A" represents less than or equal to 19 hours of rest; "B" represents more than 20 hours of duty time.

Fatigue as contributory factor

When fatigue was acknowledged as a contributory factor in the causation of safety events, it was only found significant for control attempts (Table 6). Nevertheless, the most interesting information was identified in the control attempt effectiveness (Figure 9). Safety investigation reports that did not exhibit fatigue as contributory factor had more positively controlled cases (63.7%) than negative ones. More importantly, when fatigue was considered a factor in the respective safety events, almost all cases demonstrated adverse outcomes (94.1%).

4.2.4. Occurrence details results on accident control classes

Occurrence categories

The distribution of accident control classes and effectiveness of controlled events for the occurrence categories indicated significant differences (Figure 10a and 10b). Controlled flight into terrain was most often recorded in uncontrolled events (50.0%). When this category was controlled, it most often included negative control attempts (87.5%). Runway excursions were, on the other hand, a few times recorded in uncontrolled state (4.5%). In addition, runway excursions were almost always

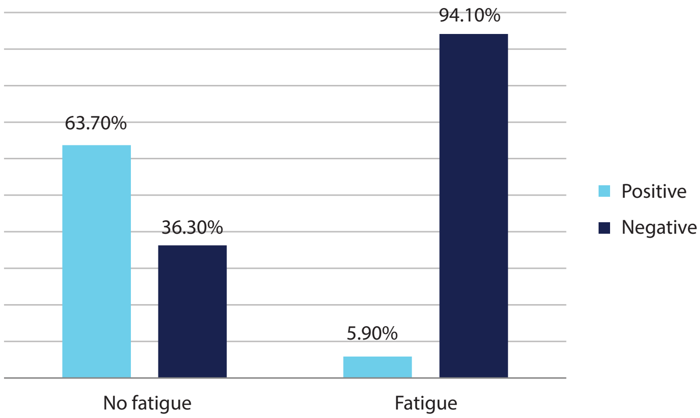

Figure 9. Fatigue as contributory factor affecting the control attempt effectiveness in controlled events as presented in a percentage distribution. (N=146 for No fatigue and N=17 for Fatigue).

recorded with negative control attempts (91.7%). Finally, system or component failures were most frequently found controlled (64.1% for non-power plant failures and 85.7% for power plant failures), and therewith most often found with correctly performed control attempts (80.0% for non-power plant failures and 78.6% for power plant failures).

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Occurrence classification

Table 10 shows the significantly found differences among the statutory occurrence classification for the neutral and uncontrolled accident control classes. More severe accidents were notably less recorded for neutral events (13.8%) when compared to incidents (52.1%) and serious incidents (37.9%). However, accidents were more frequently the result of uncontrolled events (30.0%) than less severe occurrences (6.3% for incidents and 19.7% for serious incidents). Even though differences are slightly less pronounced for the controlled accident control class, the attempt to control the event and alleviate the outcome resulted in considerable differences. It seems that the controlled incidents and serious incidents were notably more involved in well performed control attempts (85.0% and 82.1% respectively) than the accident class (47.0%).

Table 10. Occurrence classification with respect to the accident control classes and control attempt effectiveness in terms of a percentage distribution.

Independent variables	Accident control classes			Outcome control attempt	
	Controlled (%)	Neutral (%)	Uncontrolled (%)	Positive (%)	Negative (%)
Accident (N=204)	56.2	13.8	30.0	47.0	53.0
Incident (N=48)	41.7	52.1	6.3	85.0	15.0
Serious incident (N=66)	42.4	37.9	19.7	82.1	17.9

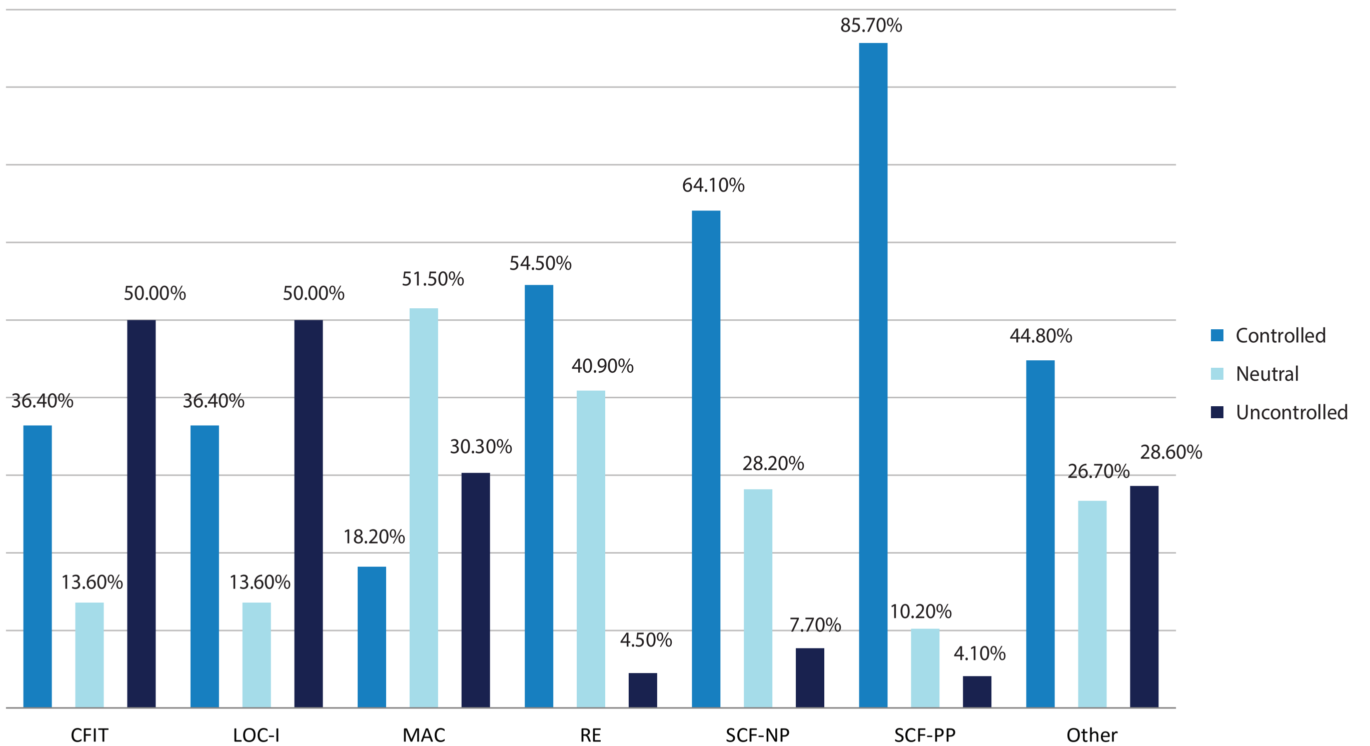

Figure 10a. Occurrence category percentage distribution with respect to the accident control classes. (N=318).

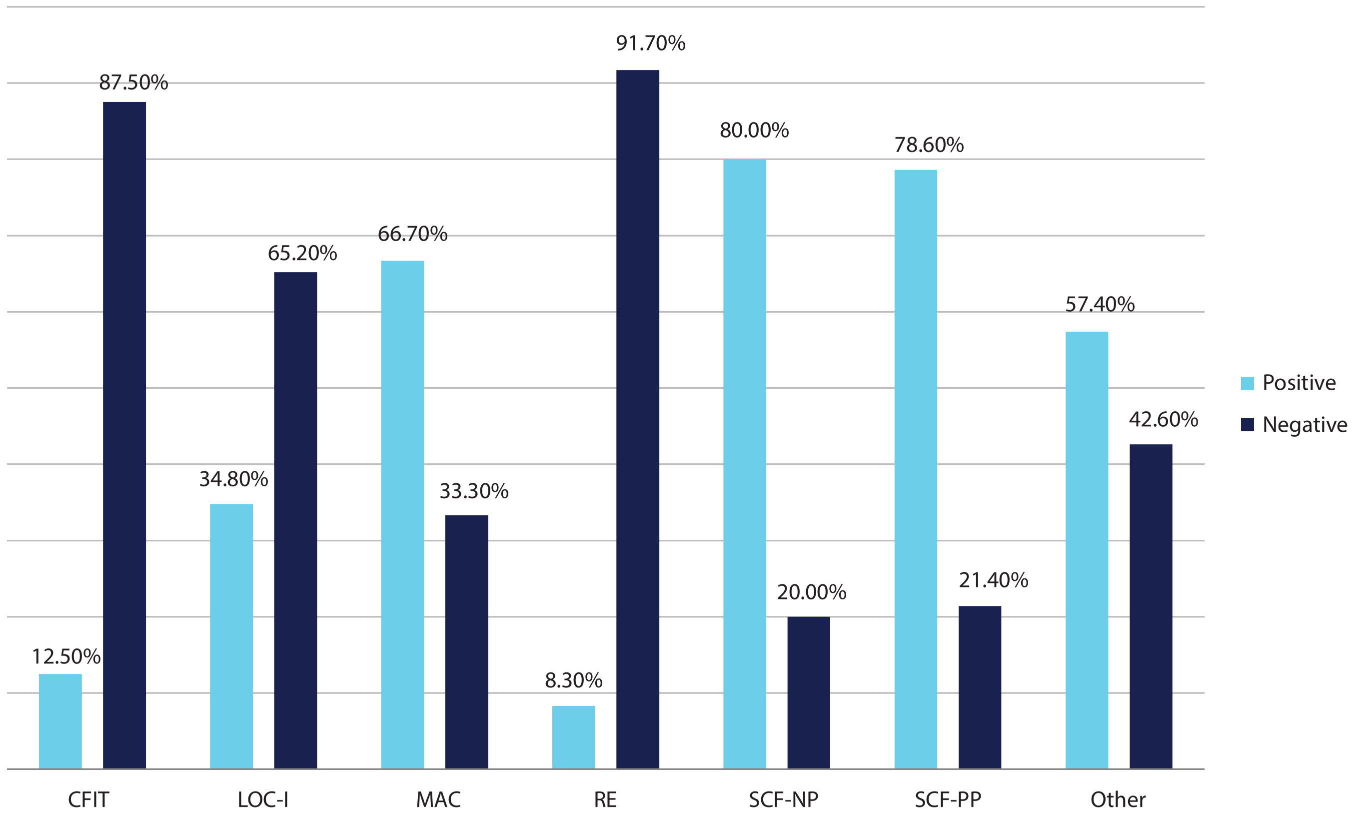

Figure 10b. Occurrence category percentage distribution with respect to the control attempt effectiveness of controlled events. (N=318).

Severity classification

The highest severity class "A" was notably more often recorded with uncontrolled events (37.2%) than the less severe classes (14.1% for "B & C" and 14.8% for "D & E") (Figure 11a and 11b). The middle severity classes "B & C" performed noteworthy with a high amount of controlled events (67.7%). Conversely, the least severe classes "D & E" seem to be most attributed to neutral events (54.3%). Focusing solely on the controlled events, it seems that the most severe events demonstrated a substantial proportion of adverse outcomes due to human action (70.4%). Severity classes "B & C" and "D & E" were depicted most frequently for the positive control attempts (80.6% and 76.0% respectively).

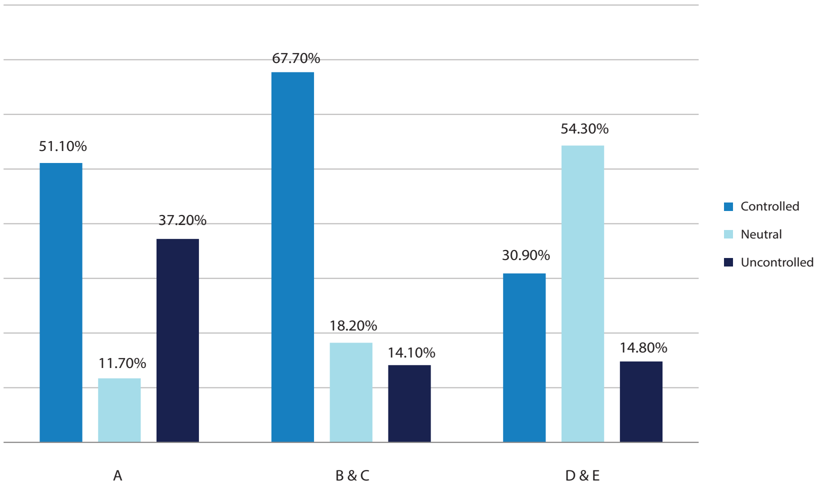

Figure 11a. Occurrence severity with respect to the accident control classes in terms of a percentage distribution (N=318).

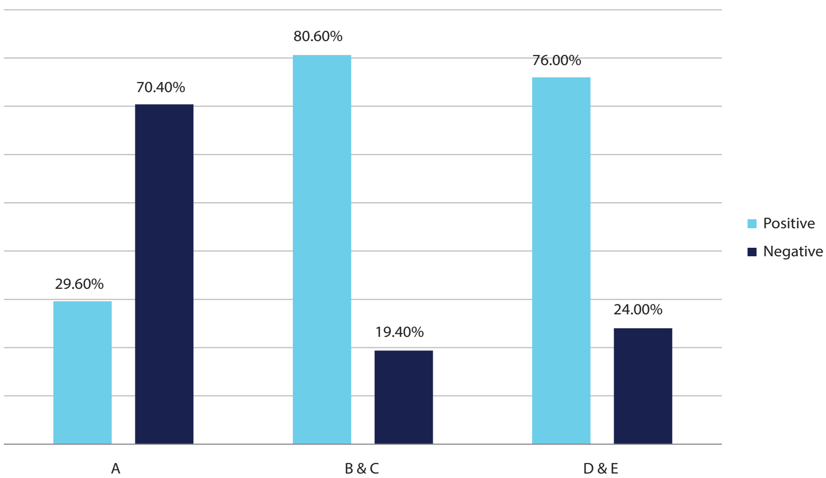

Figure 11b. Occurrence severity with respect to the control attempt effectiveness of controlled events in terms of a percentage distribution (N=318).

Types of injury

The types of injury involved in safety events were found to have a certain association with the accident control classes (Table 11). Safety events that resulted in one or more fatalities were very often associated with uncontrolled events (42.1%). However, it seems that most non-fatal events were more associated with both neutral and controlled events when compared to its fatal counterpart (32.5% and 54.1% respectively). Events that involved serious injuries were not found significantly different from those that did not involve these injuries (Table 7). However, events with minor or no injuries were less involved in uncontrolled occurrences (14.9%). Besides, the remaining events that did only involve serious or fatal injuries were not often recorded for neutral accidents (10.9%). It furthermore seems that the involvement of both fatal and serious injuries was most frequently attributed to negative control attempts (80.7% and 71.4% respectively). Then again, when the occupants on-board sustained minor to no injuries, it was frequently associated with positive control attempts (72.6%).

Table 11. Injury types with respect to the accident control classes and control attempt effectiveness in terms of a percentage distribution.

Independent variables	Accident control classes			Outcome control attempt	
	Controlled (%)	Neutral (%)	Uncontrolled (%)	Positive (%)	Negative (%)
Fatal injuries					
Yes (N=122)	47.1	10.7	42.1	19.3	80.7
No (N=194)	54.1	32.5	13.4	78.3	21.7
Serious injuries					
Yes (N=47)	59.6	12.8	27.7	28.6	71.4
No (N=269)	50.0	26.1	23.9	63.7	36.3
Minor/no injuries					
Yes (N=181)	58.0	27.1	14.9	72.6	27.4
No (N=102)	45.5	10.9	43.6	19.6	80.4

4.2.5. Extent of safety investigation reports

Certain sections of safety investigation reports, including the total word count, were found statistically significant for the accident control classes. However, all sections and word counts were significant for the human control effectiveness of controlled events (Table 7 and Appendix IV). Each section was separately recorded with the number of words. However, the accumulation of each of the sections, which represents the total word count, presented similar results among the separate and total perspectives (Appendix V). The total word count and number of recommendations are hence only mentioned in the results.

From the results it seems that neutral events are more frequently analysed in less extensive reports (31.3%). Moreover, the largest safety investigation reports seem to be more focussed on controlled events (66.3%) and less focussed on uncontrolled events (17.5%) with respect to the other reports lengths. When controlled events are considered, the smallest reports are often associated with positive control attempts (83.3%). This distribution between negative and positive control attempts gradually changes when the length of reports increases. The longest report size is therefore depicted with the most negative control attempts (64.2%).

Similarly, the quantity of published recommendations is found to be associated with the control attempt effectiveness. When the event did not comprise of sufficient safety issues, thus indicated by zero recommendations, nearly all cases were considered as positive control attempts (82.3%). When more recommendations were published (i.e. one to six recommendations), the control attempt effectiveness changes wherein negative outcomes were recorded slightly more (54.0%). Finally, with more than seven recommendations published the involvement of adverse outcomes increased to 60.8%.

4.3. Severity induced bias of safety events' outcomes

With respect to fulfilling the first sub research question: "Is there a relation between the frequency analysis of the new taxonomy, severity classification of the occurrences and analysis of the length of accident investigation reports?", this section presents the results of factors that indicate a significant relation to the extent, as derived from the word count, of the respective safety investigation reports. Table 12 shows these results from the Chi-square analysis.

Table 12. Chi-square analysis results for the independent variables of occurrence details and aircraft and flight specifics with respect to the safety investigation report categorised word count.

Independent variables	Total word count		Number of recommendations	
	Pearson Chi-Square value	Significance	Pearson Chi-Square value	Significance
Occurrence details				
Occurrence classification	59.749	**0.000***	42.812	**0.000**
Occurrence severity	58.854	**0.000**	47.577	**0.000**
Occurrence category	36.621	**0.006**	10.089	0.608
Fatal injuries	41.948	**0.000**	36.581	**0.000**
Serious injuries	28.655	**0.000**	7.080	**0.029**
Minor/no injuries	23.050	**0.000**	20.497	**0.000**
Aircraft and flight specifics				
Aircraft Type	9.334	0.156	11.082	**0.026**
Aircraft weight	4.436	0.218	5.001	0.082
Flight type	8.916	**0.042**	7.210	**0.027**
Flight sub type	2.704	0.440	2.859	0.239

Note: All results from the statistical Chi-square analysis are presented and do not all represent significant data.
* Bold type and underlined represents a significance of $P < 0.05$

4.3.1. Occurrence classifications on bias of safety investigations

Occurrence classification on extent of safety reports

The extent of safety investigation reports is evidently depicted by the statutory occurrence classification (Figure 12a). To elaborate, less severe incidents and serious incidents were most often published in the least extensive word-count category (41.7% and 40.9% respectively). Accidents, on the other hand, were far more often reported in the largest word-count category (37.7%). This depiction is even more significant when compared to incident reports (2.1%). With respect to publishing safety recommendations, serious incident and incident reports were most frequently found without publishing safety recommendations (60.6% and 64.6% respectively) (Figure 12b). Accidents, however, did present an equal distribution among the quantity of published recommendations.

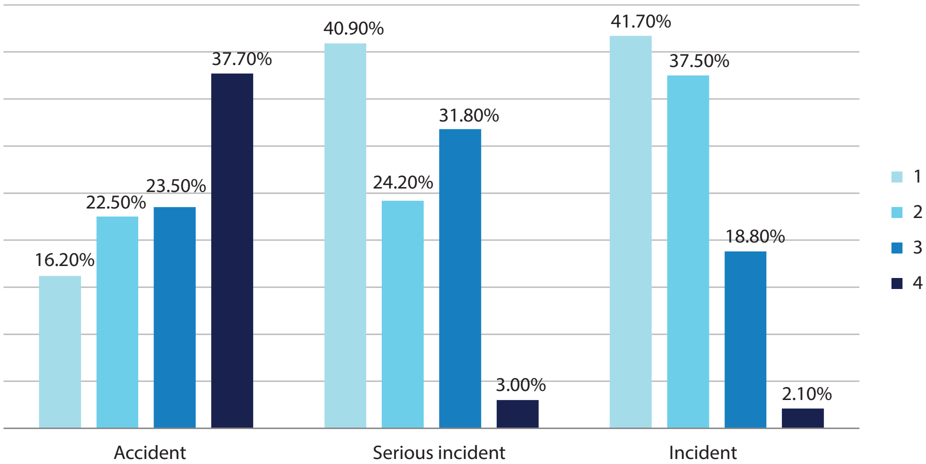

Figure 12a. Percentage distribution of occurrence classes with respect to the classified length of safety investigation reports. Note. Word count classes are noted with 1 = ≤ 2.500; 2 = 2.501- 10.000; 3 = 10.001 - 24.000; 4 = ≥ 24.001.

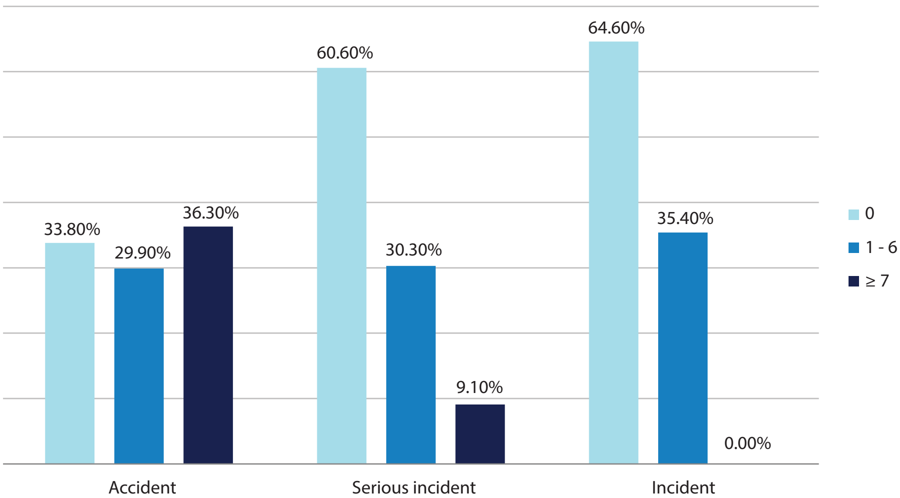

Figure 12b. Percentage distribution of occurrence classes with respect to the number of published safety recommendations. Note. The numbers presented in the graph represent the actual amount of published safety recommendations of a safety investigation report.

Occurrence severity classification on extent of safety reports

Similar to the occurrence classification before, the extent of safety investigation reports are reflected in the severity classification of safety events (Figure 13a). The least severe occurrences were mostly found in the least extensive reports (35.4% for "B & C" and 35.8% for "D & E"). This notion extends to the highest severity class, which was most frequently found in the largest reports (42.8%). To put this into an uncategorised perspective, the word-count distribution of all 297 analysed safety investigation reports with respect to the severity classes indicated similar results

(Figure 13b). A gradual transition is found for the classification of severity, in which the least severe occurrences presented the least amount of words and most severe occurrences presented precisely the opposite.

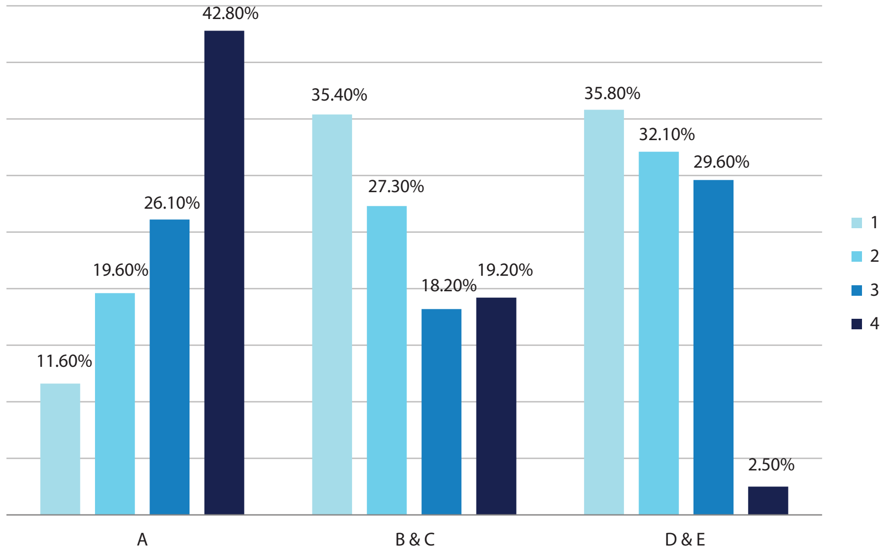

Figure 13a. Severity classes with respect to the classified extent of safety investigation reports in terms of a percentage distribution. Note. Word count classes are noted with 1 = ≤ 2.500; 2 = 2.501- 10.000; 3 = 10.001 - 24.000; 4 = ≥ 24.001.

The highest severity class accidents most frequently published more than seven safety recommendations (40.6%) (Figure 14). Less severe events publish less frequently in general and, relative to more severe events, far less often in high quantity.

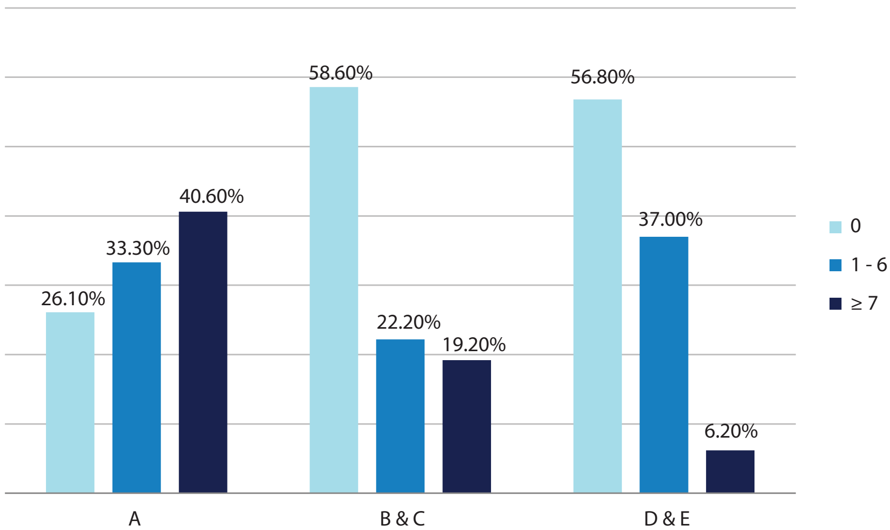

Figure 14. Severity classes with respect to amount of published safety recommendations of safety investigation reports in terms of a percentage distribution. Note. The numbers presented in the graph represent the actual amount of published safety recommendations of a safety investigation report.

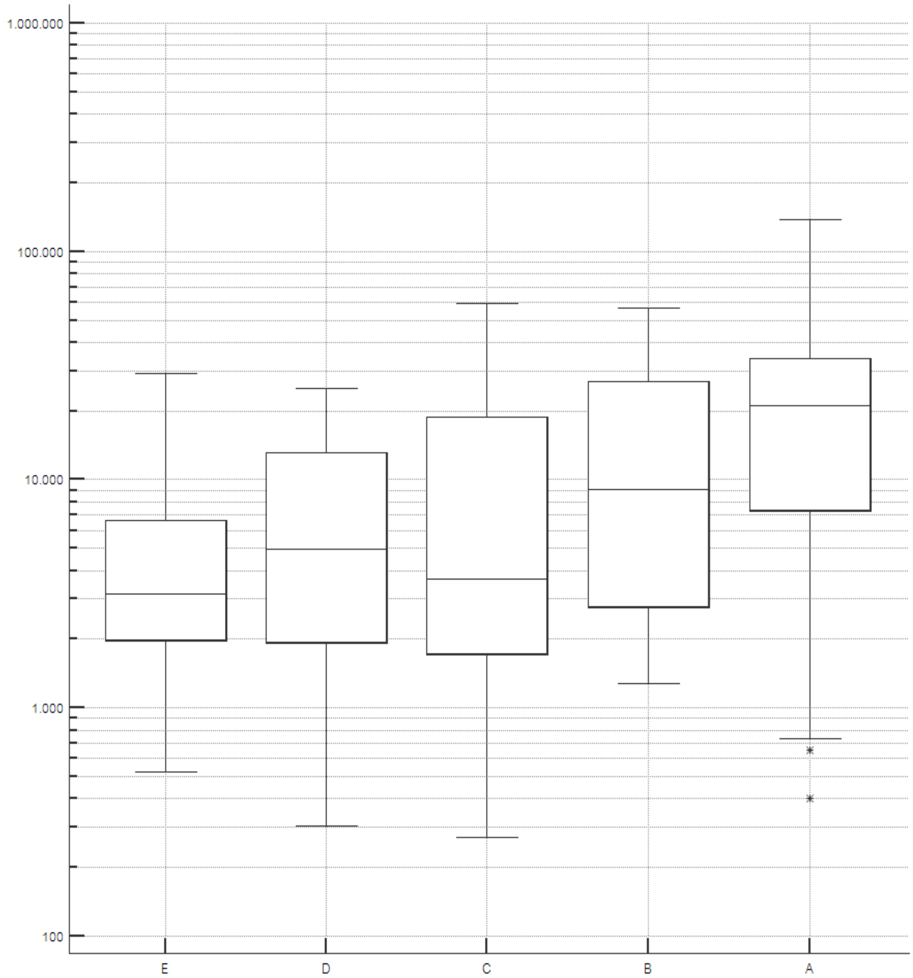

Figure 13b. Logarithmic scale of the extent of all analysed safety investigation reports as found by the total word count. Note. Outliers are considered for reports outside the 1.5 times boxplot range (i.e. Q1 – 1.5 x Interquartile range (IQR) and Q3 + 1.5 x IQR) and are identified by an asterisk.

Occurrence category on extent of safety reports

Categorisation of occurrences seems to have an effect on the extent of safety investigation reports (Table 13). Events such as (near) mid-air collisions were notably less extensively reported than controlled flight into terrain events. Then again, controlled flight into terrain is the least frequently recorded in the smallest of safety investigation reports. It also seems that most system or power plant related events were reported in small investigation reports.

Table 13. Chi-square analysis results for the independent variables of occurrence details and aircraft and flight specifics with respect to the safety investigation report categorised word count.

Occurrence category	Total word count			
	≤ 2.500 (%)	2.501 - 10.000 (%)	10.001 - 24.000 (%)	≥ 24.000 (%)
CFIT (N=23)	4.3	43.5	13.0	39.1
LOC-I (N=47)	14.9	31.9	31.9	21.3
MAC (N=33)	21.2	36.4	36.4	6.1
RE (N=22)	18.2	22.7	22.7	36.4
SCF-NP (N=39)	35.9	12.8	33.3	17.9
SCF-PP (N=49)	32.7	24.5	14.3	28.6
Other (N=105)	29.5	20.0	21.9	28.6

Note. CFIT = Controlled Flight into terrain; LOC-I = Loss of Control in-flight; MAC = (near) Mid-air Collisions; RE = Runway Excursion; SCF-NP = System or Component Failures – Non Power Plant; SCF-PP = System or Component Failures – Power Plant.

Type of injury on extent of safety reports

Events that included discernible injuries, indicated by either serious or fatal injuries, were found significantly associated with the length of safety investigation reports (Table 14). When fatal injuries were implicated in an event, it was most likely to be reported in an extensive investigation report (41.0%) with a high quantity of safety recommendations (41.0%). Notwithstanding the results of fatal injuries, events that involved serious injuries were found to be most likely reported in the most extensive report category (53.3%). Besides, when minor or no injuries were involved in an event, it was reported relatively equal in extent for the three largest investigation report classes. When no minor injuries were reported, thus indicating at least the involvement of serious injuries, the frequency of safety investigation reports was found highest for the largest reports (39.2%).

Table 14: Type of injury with respect to the length, as expressed in number of words, of safety investigation reports.

Occurrence category	Total word count				Amount of recommendations		
	≤ 2.500 (%)	2.501 - 10.000 (%)	10.001 - 24.000 (%)	≥ 24.000 (%)	0 (%)	1 -6 (%)	≥ 7 (%)
Fatalities							
No (N=194)	35.1	27.3	22.2	15.5	55.7	28.9	15.5
Yes (N=122)	9.0	21.3	28.7	41.0	24.6	34.4	41.0
Serious injuries							
No (N=269)	27.5	25.3	27.1	20.1	46.5	30.5	23.0
Yes (N=47)	10.6	23.4	10.6	55.3	27.7	34.0	38.3
Minor/no injuries							
No (N=102)	9.8	21.6	29.4	39.2	24.5	38.2	37.3
Yes (N=181)	33.1	22.1	23.8	21.0	51.9	26.5	21.5

Note. CFIT = Controlled Flight into terrain; LOC-I = Loss of Control in-flight; MAC = (near) Mid-air Collisions; RE = Runway Excursion; SCF-NP = System or Component Failures – Non Power Plant; SCF-PP = System or Component Failures – Power Plant

4.3.2. Aircraft and flight associated bias

An aircraft's physical size, as depicted by its weight class or type was not found to be statistically different from the extent of safety investigation reports (Table 12). Despite this, a difference was found for the type of flight (Figure 15). When a safety report concerns commercial air traffic, it was most often reported in the largest report length class (30.0%).

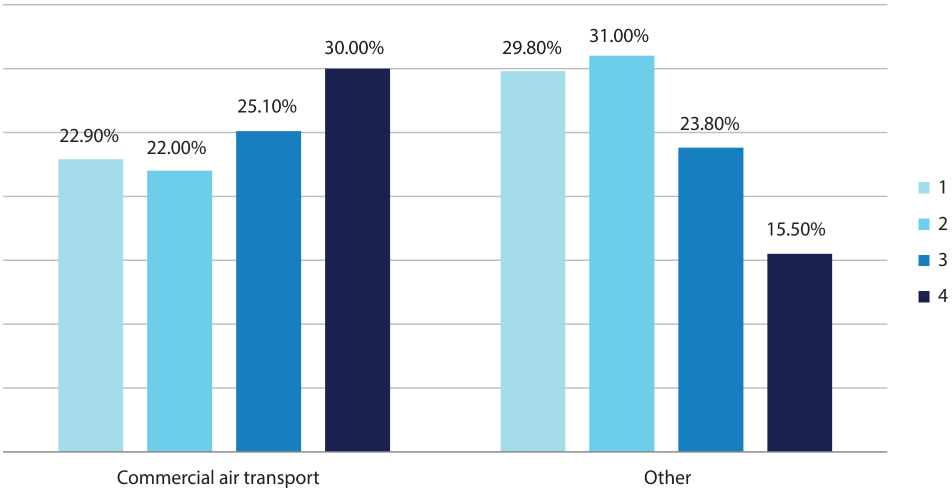

Figure 15. The type of transport with respect to the classified length of safety investigation reports in terms of a percentage distribution. Note. Word count classes 1 = ≤ 2.500; 2 = 2.501- 10.000; 3 = 10.001 - 24.000; 4 = ≥ 24.001.

4.4. Correlation statistics and exploration of relations

4.4.1. Spearman's rho correlation

Extent investigation reports by injury type

Table 15 presents the correlations of injury types for the extent of safety investigation reports. Results from the Spearman's rho correlation analysis show that the higher the fatality count is, the greater the extent of investigation reports is. It seems that the amount of published recommendations had a corresponding correlation. Moreover, the amount of serious injuries demonstrated similar results. As expected, the opposite of these results were found for minor or no reported injuries.

Table 15. Spearman's rho correlation analysis of the types of injury with respect to the length of safety investigation report as classified in report sections and which were quantitatively expressed in number of words.

Independent variables		Dependent variables					
		Total words	Factual section	Analysis section	Conclusion section	Recom-mendation section	Quantity recommen-dations
Fatalities	ρ^a	0.488**	0.474**	0.451**	0.342**	0.408**	0.408**
	p^b	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Serious injuries	ρ	0.231**	0.227**	0.208**	0.176**	0.173**	0.169**
	p	**0.000**	**0.000**	**0.000**	**0.002**	**0.002**	**0.003**
Minor/no injuries	ρ	-0.178**	-0.177**	-0.144*	-0.076	-0.152*	-0.103
	p	**0.003**	**0.003**	**0.015**	0.201	**0.010**	0.083

[a] Spearman's rho value is indicated with "ρ".
[b] Significance is indicated with "p".
* Correlation is significant at the significance level P < 0.05
** Correlation is significant at the significance level P < 0.01
Note. Positive Spearman's Rho values indicate a relational increase of the respective variables. A negative value indicates a relational decrease.

4.4.2. Multivariate Chi-square analysis

Multivariate Chi-square analyses have been employed for the location of origin and severity classifications with respect to the extent of safety investigation reports (Appendices VI to VIII). First of all, it was found that there are significant differences for Australia among the severity classification and extent of reports when considering the country of origin (Appendix VI). The largest report size was only recorded for "A" class severity accidents. In addition, when the smallest report size was considered, it accounted for 72.7% in the D and E severity classes. The same analysis has been employed for the regional classification (Appendix V). Significant differences were additionally found for the regions all considered regions. It was found that indeed most severe events were recorded in the largest report sizes, while lesser severe events were depicted in smaller report sizes.

Third, the statutory occurrence classification was only found significant for the regional classification, albeit for all concerned regions (Appendix VI). Once again, the shortest reports were found associated with less severe events (i.e. incidents and serious incidents), while longer reports focus on the more severe events (i.e. accidents).

Another multivariate Chi-square analysis was employed for the length of safety investigation reports and type of reports (i.e. accident, serious incident and incident) with respect to the accident control classes to reveal if differences exist across the different types of reports. First, the controllability was only found significant for the accident reports [$\chi 2$ (3, N = 175) = 8.142, $p = 0.043$] (Appendix IX). The most extensive accident reports were found mostly focussing on controlled events (78.5%), while the three smaller report lengths were found less focussed on controlled occurrences. Accident reports on controlled events were also found significantly different [$\chi 2$ (3, N = 115) = 8.419, $p = 0.038$], with most negative control attempts (66.7%) reported in large reports while most positive control attempts were reported in the least extensive reports (about 65 % for both length groups) (Appendix X). Publication of recommendations were found different among the three report types for the control attempt effectiveness [$\chi 2$ (2, N = 115) = 18.676, $p = 0.000$] (Appendix XI). Accident reports were mostly published when control attempts resulted in adverse outcomes, while incident reports were found to always publish recommendations for negative control attempts (33.3%).

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Chapter 5

Discussion

Contents

Discussion

"People often confuse an explanation of causes with a justification or acceptance of results. However, understanding 'why?' is a question separate from the explanation itself"

- Jared Diamond, 1997

The fifth chapter is aimed at discussing, interpreting and placing the results in practical perspective as presented in the previous chapter. Factors that demonstrated differences for the controllability of safety events formed the core of this research (Section 5.1). Differences between the current industry classification and the controllability taxonomy were explored to indicate the representability of the new taxonomy compared to the standard classification (Section 5.2). Moreover, it was hypothesised that the severity of safety events drives an safety investigation authority's resource allocation and overall attention towards such events. The results concerning the extent of safety investigation reports are discussed whether bias can indeed be found in such reports (Section 5.2). By exploiting the taxonomy and findings of the previous sections, the generation of selection priority criteria are speculated in Section 5.3.

5

5.1. Associations with controllability and intervention effectiveness in safety events

When considering the overall results of the study, the controlled events were depicted in a significant proportion of the concerned safety events, indicating that most events comprised of situations and circumstances that could be controlled and thus alleviating the outcome. Neutral event were depicted in a quarter of all events, which indicates that about 25% of all the events can be found in standard operating manuals or is related to normal piloting skills, all of which can be trained or taught. Additionally, most of the control attempts effectively alleviated the end-states of the respective events. Although this finding may present a positive distribution of alleviated end-states and representation of a good control performance, substantial improvements in effective control attempts could still be obtained. Therefore, emphasise should be placed on the factors affecting the control attempts in order to improve the overall control element in the development of safety events.

The differences across the severity classes for all cases with respect to only the controlled events were not found for classes “A” and “B”. However, a ten percent difference was computed for the “C” severity class, in which this class presented ten percent more controlled events than when all events are concerned. Moreover, less controlled events were found for classes “D” and “E” with respect to the overall distribution. These results suggest that computations based on severity may misjudge the overall distribution of events if safety initiatives are centralised on controlled events.

Even though the distribution of accident control classes for the country of origin was not found significant when considering the control attempt effectiveness, Americans were found performing significantly worse, in comparison to other nationalities, when presented with events that were controllable. Australians and European nationalities, on the other hand, most often did control such events when presented with one. Research has shown that cultural differences contribute to causal factors in aviation accidents (Li, et al., 2007; Strauch, 2010). In specific for pilots originating from USA, it was found that skill-based errors contributed for more than 60% of the recorded occurrences, therefore validating the findings in this particular study (Li, et al., 2007).

Also, variations in time did not affect the distribution of controlled, neutral and uncontrolled events for a time period of 25 years. These results suggest that no effective changes are made in the improvement of safety by the state of the events (i.e. controlled, neutral or uncontrolled), but also the effectivity of personnel in alleviating the controlled events. However, current industry safety performance indicators have shown that safety has improved over the same time period by means of accident rates (Flightglobal, 2016). This definition of safety by just the adverse outcomes may misguide the perception of safety in today’s low accident numbers.

Aside from this, the system that enables personnel to control such events is the aircraft itself; newer aircraft were found less involved in uncontrolled events. Neutral events were also significantly more found for newer generation aircraft, suggesting that more events can be controlled in a reactive manner or by standard procedure. This may indicate that technological advancements and developments of the recent era (e.g. ground proximity warning systems, autopilot, navigation systems, etc.) support this phenomenon, placing the human element with more chance to actually control events (Airbus, 2015). Similarly, commercial air traffic was less depicted in uncontrolled events, suggesting that differentiating factors such as highly trained personnel and general nature of the flight (e.g. business and passenger) provide better performance in terms of uncontrolled states. Statistics in aviation support this finding, wherein commercial air traffic is indeed less likely to be involved in accidents (Boeing, 2015). Categorisations of occurrences also indicated significant differences among controllability and effectiveness in intervention attempts. Controlled flight into terrain and loss of control in-flight presented a significant proportion of uncontrolled events, validating the known areas of uncontrollability. Considering runway excursions, although found most often in controlled events, was almost always adversely impacted with control actions, indicating an area that requires critical treatment. Statistics affirm these findings, as these specific categories are known as “high risk accident occurrence categories” (ICAO, 2015; Airbus, 2015). Moreover, the system or component failure related events were mostly considered controlled, in which these categories presented excellent success rates of controlling events positively, revealing that crew members are sufficiently trained to successfully control events of this nature.

Pilot experience was subsequently found to help avoiding the uncontrolled state of safety events, but also the effectiveness in controlled events. Research in risk of crash involvement regarding flight experience found similar results in which flight experience of more than 5.000 clocked flight hours are less likely involved in air crashes (Li, et al., 2003). This may indicate that, although a pilot’s experience is a career long endeavour, further research could be done on the differences in skill-level due to differences in experience maturity to reveal the factors that contribute to improvements in control attempt effectiveness, regardless of time dependent experience. Events that occurred within five hours of duty time, was twice as often uncontrolled as events after five hours of duty, suggesting a better alertness of aircrew in longer duty time periods. This is contradictory in terms of expected human performance degradation over time (e.g. due to boredom on long haul flights, the time awake, etc.). Duty times incorporate the clocked hours when reporting for duty, causing less hours of actual operational duty with respect to the five hour demarcation. Another explanation may be that operational procedures at the start of the flight (e.g. taxiing, take-off, climb) might be more sensitive to an uncontrolled state than those procedures in later stages of the flight (e.g. en-route, descend, landing). Long rest periods also helped avoiding the uncontrolled state of safety events. This supports the widely known issue in aviation that Flight Duty Time (FDT) limitations are associated with generating fatigue in the cockpit (ECA, 2012). Fatigue was also found to degrade a pilot’s performance to an almost unrecoverable state when presented with controllable events. Research has similarly shown that fatigue affects decision making of pilots by their physiological and cognitive state and overall flight performance (Michalski & Bearman, 2014).

5.2. Controllability and severity classifications

The severest classified occurrences (i.e. "A" and accident classes) seem to be more recorded for the uncontrolled state of events, indicating that this type of accident control class is more sensible to severe outcomes. Differences found in the control attempt effectiveness across the severity and occurrence classifications were revealed to be significant. Most severe class "A" was attributed with mostly negative control attempts, while accidents were evenly received for this distribution. However, the lesser severe classes and classifications revealed that most control attempts were correctly performed. These results indicate that less severe events may have been prevented from more adverse outcomes due to high proficiency of the concerned air crew. Similarly, the implication of fatal and serious injuries were found associated with the effectiveness of outcome control attempts, in which most negative controlled events were attributed to these types of injury. Then again, fatal injuries were most often depicted in uncontrolled events. This may indicate that uncontrolled events do affect the severity of its outcome. Even though these results can be expected, it does confirm that the severity of safety events are related to its type of accident control class.

5.3. Safety investigation bias in safety events

Safety investigation authorities were found to put minimum investigative resources on neutral events, as these were most often found in the least extensive reports. Moreover, the events that included well executed controlled events (which are mostly found in less severe events) were less thoroughly investigated than those that had adverse outcomes due to the attempt (which are mostly found for severe events). These results indicate that the issues raised by the poor performance of control actions contribute to the interest of investigations to improve safety rather than learning from those events that performed noteworthy. Similarly, most recommendations are published for a high proportion of negative outcomes and when no recommendations were published, it was most often found for well executed control attempts. These results may suggest that the effectiveness of a control attempt does indicate whether an event accommodates issues that need rectifications through the publication of safety recommendations or that the interest of safety investigations on negative events is similarly depicted in the publication of safety recommendations.

From the data concerning occurrence and severity classifications, it was found that more severe occurrences, namely accidents and "A" severity class events, were most often reported in the largest safety investigation reports and with the most published safety recommendations. These large reports also were mostly focussed on controlled events and the negatively attempted ones. The largest reports were, additionally, mostly focussed on occurrence categories that are acknowledged as industry wide issues, namely controlled flight into terrain, runway excursion and loss of control in-flight. As expected, the inclusion of fatal or serious injuries was associated with larger report sizes. When the count of these injuries increases, the length of the respective investigation reports increased as well, indicating that the more severe events are more thoroughly reported, as could be expected. Moreover, commercial air traffic related events were also more extensively reported than other types of operations, indicating that commercial traffic gains more attention from investigation authorities. From these results it can be argued that severe events, industry known issues or events with commercial operations are indeed associated with more elaborate reports and thus indicating bias.

Suggesting from the two previous paragraphs, it seems that the focus of safety investigations is uncovering the details that are related to unfavourable, adverse events. Accordingly, learning from mistakes is favoured over learning from successes. These mistakes were, in addition, mostly found in thoroughly reported severe events, while successes are mostly found in less thoroughly reported and less severe events. It is therefore claimed that too much emphasis is placed on the adverse outcomes. Concerning this finding, Hollnagel (2014) described two safety perspectives on the management and perception of safety: Safety-I and Safety-II. Safety-I is the perspective on events that go wrong, while Safety-II focusses on the events that go right. Hollnagel stated that safety management is mostly aimed at the former, while the number of events that go wrong is at an all-time low as everything usually goes right. Therefore, combining the two ways of thinking is "the way forward" for the management of safety. By considering the controllability before the classification of occurrences or institution of safety investigations, investigative resources could be allocated and managed more appropriately on both types of perspectives.

It can be stated that safety investigation authorities, besides the severity induced bias, focus mainly on negative events: learning from failure is favoured over learning from success. This indicates that uncovering the cause of errors is more interesting to safety investigations authorities to improve safety as depicted by Safety-I.

5.4. Selection priority criteria

It has been discussed that safety investigation authorities focus on the “bad” rather than the “good” in safety events. In addition, the controllability reveals the overall performance in safety events in the industry in a different light than the standard severity rates. That is, the ratio of controlled and uncontrolled events and the ratio of control attempt effectiveness for controlled events. Organisations and authorities should therefore focus on improving both ratios by indicating the controllability of safety events before instituting safety investigations. This way, safety initiatives are directed to improving the overall safety performance in aviation as expressed by the controllability, rather than just adverse outcomes.

Investigations can be initiated in multiple ways; it may be subject to obligatory requirements, the authority’s interest or requested by different channels (e.g. governments). Accidents and serious incidents are required by law to be supported with an investigation. However, the extent of such investigations is the respective safety investigation authority’s determination. This extent was found in the literature (See section 2.2) to be associated with the severity, social impact, public interest, type of operation or impact based on damage costs, in which all priority aspects focus on the prospect of safety in terms of adverse outcomes. Considering an accident’s or serious incident’s controllability prior to basing the extent on these aspects, a more representative distribution of resources and thereby extent of an investigation can be obtained for the improvements in safety (performance). However, obtaining the controllability of a safety event is only possible with an initial inquiry to extract this information. This initial inquiry of small scale data gathering is therefore a requirement in order to utilise the taxonomy to determine the extent of an investigation.

Incidents are not required for investigation, but are investigated nonetheless, albeit far less thoroughly. Resource restraints are one of the few reasons incident investigations are not as often or as thorough investigated in comparison to serious incidents or accidents. With the analysis it was found that incidents are seldom uncontrolled and mostly recorded with neutral control states. In addition, controlled attempts showed a high performance of correctly executing control attempts. It is therefore stated that a substantial proportion of information is related to the "good" in safety events. Since the investigative resources for incidents are scarce and most positive lessons can already be extracted from both accidents and serious incidents, the rare uncontrolled events for incidents is determined critical for instituting an investigation. Then again, in order to obtain an event's controllability, a small scale inquiry may be mandatory. However, incidents, as defined by the term itself, do not include fatalities or serious injuries, meaning that all involved crew members can be requested for interviews to extract information for the controllability. In addition, air safety reports are commonly used in aviation to report incidents as part of a voluntary reporting system for service providers or on an industry level (European Commission, 2012; European Commission, 2014). These reports are concise and only demand essential occurrence related information (e.g. narrative of occurrence, level of severity, aircraft information, etc.). Incorporating the new taxonomy in these reports could unveil the controllability without the need of a small scale inquiry from safety investigation authorities. More importantly, the information through a common agreed field in occurrence reporting schemes (i.e. controllability) can provide this information in a more effective way, but also in greater scale. Significant amounts of data related to the controllability could reveal trends, which could be utilised to allocate resources according the critical areas.

5.5. Limitations of the study

The research sample employed in the study was chosen for the interlinking of data of multiple studies combined. However, no sampling methods have been generated to ensure a suitable sample for this study in particular, with respect to the analysed statutory occurrence classes. Although all classes were addressed in the sample, an even distribution among the classes could indicate stronger and more discriminate results concerning the differences across the safety investigation reports. Furthermore, the inter-rater reliability test was performed by five students with the same study (including the researcher). However, all raters were inexperienced in performing such tests. This was additionally apparent in subsequent interviews, which likely affected the results of the tests. It can therefore not be stated that the same reliability and validity can be expected for the use of this taxonomy by experienced professionals in safety studies.

The scope of this study is focussed on safety investigations conducted on a national scale. In specific, safety investigation authorities are independent bodies that investigate significant events that help to improve safety for all of aviation. This separates safety data of smaller scale investigations (e.g. service providers), from the investigation's at a state level and potentially restricting the data to only the most adverse events. Karanikas' (2015) employed an identical study at a specific organisation on a national level. With regard to the accident control classes, the results of the study differed noteworthy from this study. About 43% of all events were devoted to both controlled and uncontrolled states, while about 13% was of a neutral state. Moreover, that specific organisation showed a remarkable effectivity in controlling events correctly, which was the case for about 87% of the controlled events. These results differ greatly from this study where effort should be placed in revealing these variations between the national and state level of safety data. Secondly, the taxonomy is only employed for demonstrating safety (performance) in the aviation industry. However, this taxonomy can be utilised for industries wherein human implication is found in the development of safety events (e.g. transport, medical and nuclear industries). Even though similarities in application of this taxonomy are identical in nature, differences arise once associated factors are considered to reveal critical areas of that particular industry.

Using the new taxonomy is aimed for any institute or organisation that seeks to reveal their safety performance by means of the controllability of safety events. However, prioritising and allocating resources with this information may be less applicable to all users of this taxonomy. Safety investigation authorities are obligated to investigate all accidents and serious incidents and may institute an investigation for incidents if gains in safety are expected. This does mean that these authorities are established for the very reason to investigate accidents and serious incidents, not incidents. The main purpose of these organisations is therefore not focussed on incidents to reveal the causation and its related factors of safety events. Resources are allocated accordingly to obtain this specific information to prevent future accidents or serious incidents from recurring. Using the taxonomy to drive resources for safety investigation authorities is therefore limited and may only help to improve the resource management, if sought by these authorities. In contrast, prioritising safety initiatives and resources with this taxonomy is more suitable for service providers. Each organisation can have different areas that require special attention to improve its safety performance that in return could be utilised to effectively allocate resources.

The study was aimed to confirm if bias was indeed associated with the severity of safety events. In order to claim this hypothesis, the word count of safety investigation reports was used to indicate differences in report length across the levels of severity. However, bias is an intricate term that may be observed in more ways than just the word count of safety investigation report. Recording the word count was the most obvious and consistent method to identify the bias (due to availability of reports), but it should be noted that the study was limited to only claim bias by the word count. Besides, a higher word count could also have been related to more available details and information of severe events (e.g. more errors, failures, aircraft damages, etc.) while less severe events included less available information. Reports therefore could have been written according the complexity of the events based on the information available and not according the bias towards the severity of such events.

6

Chapter 6

Conclusions and recommendations

Contents

Conclusions and Recommendations

"A fact acquires its true and full value only through the idea which is developed from it."

- Justus von Liebig, 1803-1873

The final chapter concludes all findings of this study and prepares for potential exploration of this field of study in future research. First, the study as a whole is described in Section 6.1. The main aims and objectives are mentioned with respect to the findings of the study. These findings are related to the research questions as formulated in the introductory chapter and will bring, by answering the research questions, the study to a closure. Certain topics of the study were not incorporated as defined by the scope, however, these delimitations formed interesting new topics for future research (Section 6.2). In addition, recommendations are made to address to use of the taxonomy and selection criteria in practice (Section 6.3).

6.1. Conclusions of the study

This study was aimed to utilise a taxonomy, based on the controllability in the generation of safety events, on safety investigation reports to compare it with the current industry classification that is based on the outcome of such events. Today, safety is commonly expressed in terms of adverse outcomes, while investigative resources of safety investigations authorities are allocated according the severity of these outcomes. Therefore, the controllability in safety events was exploited (1) to indicate the differences among the two classifications (i.e. current industry and controllability classifications), (2) to identify bias towards the outcome of safety events, (3) to propose an alternative way on allocating resources for safety investigations and (4) to demonstrate if the taxonomy is a more representative way to indicate safety performance.

The approach of the study was aimed to apply the new taxonomy on a sample of safety investigation reports, since this source of information is closely related to the expected use of the classification: occurrence data. This application was performed to indicate areas in which the implementation of the taxonomy is beneficial, but also in which it would be difficult to exploit. These areas were determined and supported by scientific literature and found in the analysis by associated factors in the controllability of safety events. These factors were analysed to indicate if it affects the controllability in the development of safety events. The most significant associations were found in three distinctive variable groups: (1) location and nationality, (2) aircraft and flight specifics and (3) human performance. Differences are present in the cockpit depending on the nationality of origin, in which Americans particularly perform significantly worse compared to other nationalities in terms of controllability. Younger, and thereby more technological advanced, aircraft are better equipped to reduce the chance of uncontrolled states. Thereby, chances are lower of uncontrolled events for commercial air traffic. In addition, pilot experience and rest periods of pilots exceeding nineteen hours helped avoiding the same uncontrolled state of events. Aside from the results that show remarkable areas for the use of the new taxonomy, duty time periods showed inconsistency with the expected results, indicating an area of difficult use.

In order to identify hypothesised safety investigation authorities' bias towards the severity classification of safety events, the length of safety investigation reports was exploited to derive the answer to this hypothesis. In addition, the association of the controllability taxonomy with the length of safety investigation reports was explored to reveal differences in extent that was attributed to the control state of such events. In this regard, bias was observed for the severity classification in which the most severe events are far more thoroughly investigated than events with lower severity. Other factors, namely (1) occurrence category, (2) type of injury and (3) type of operation, were found contributing to the severity induced bias of safety investigation authorities. The controllability also indicated a relation with the length of safety investigation reports. Controlled events were found most often explored in the longest reports, in which emphasis was placed on negative control attempts. On the other hand, control attempts that were performed correctly were most often reported in relatively short reports.

This distribution of control attempt effectiveness was found essential for the generation of (selection) priority criteria, as it indicates the investigation philosophy of safety investigation authorities who focus on poor performance and adverse outcomes, rather than focussing on well performed control attempts in safety events as depicted by the Safety-I perspective. Moreover, the ratios of controlled by uncontrolled events and the control attempt effectiveness must be incorporated in such priority criteria as increments in both ratios improve the overall safety performance in aviation. It is therefore claimed that priority criteria, with the use of the controllability in safety events, must be applied on safety events before instituting investigations to allocate investigative resources to focus on the improvements of safety performance in terms of these ratios and therewith excluding bias towards adverse outcomes.

Accidents and serious incidents are required by law to be supported with an investigation; therefore *selection* of events is not applicable. The exploitation of the taxonomy as *priority* criteria provides an investigative body with information to allocate resources more appropriately on the areas of special attention and more evenly among the cases with respect to controllability, rather than the impact of severity or coverage of media. In order to state an event's controllability, a brief initial inquiry must provide this information and should subsequently guide the extent of the investigation.

Incidents, on the other hand, are not required for investigations and due to resource restraints are not as often or as thoroughly investigated as accidents or serious incidents. The exploitation of the taxonomy should focus on the information that is seldom in nature for this occurrence class: uncontrolled incidents. Then again, information of controllability can only be obtained with data gathering. Two solutions for incident investigation selection have been provided: (1) initial inquiry and (2) occurrence reporting scheme addition. First, an incident investigation must be initiated once the initial inquiry states an uncontrolled event. The second option is the creation of a new element in occurrence reporting schemes, wherein witnesses in the act can report what control class is applicable and thereby provide information for safety investigation authorities without the need of an initial inquiry. Moreover, due to larger amounts of data related to controllability by such solution, trends can reveal the overall safety performance and areas of special attention. Safety investigation can with the use of this knowledge prioritise resources on critical areas accordingly. The second option is decided as the most desirable solution.

When considering these aforementioned findings of the controllability of safety events, severity induced bias and focus of investigations on adverse events it is claimed that the taxonomy can indicate safety performance in a more representative manner than the commonly used accident rates. First of all, the controllability indicates whether events were dependent on chance, indicated by uncontrolled events, or actually comprised of potential controllability to intervene in the development of such events. This taxonomy can furthermore be utilised to depict the control attempt effectiveness in order to demonstrate the control performance of implicated personnel. An event's associated factors to the controllability or intervention effectiveness can furthermore indicate areas that require special attention to improve safety in a more focussed manner. Besides, it was found that the safety performance in aviation did not change for a time period of 25 years. It is however often claimed that safety has substantially improved in this particular time frame in terms of accident rates. In order to improve safety by means of the controllability taxonomy, target levels must be set at higher ratios of controlled by uncontrolled states and positive by negative control attempts. In terms of this taxonomy, safety improves with higher proportions of controlled events, enabling the controller with actual chance to control an event, and greater control attempt effectiveness, increasing the human control performance to alleviate adverse outcomes. In this regard, safety performance as indicated by the controllability of safety events comprises as a more representative manner to indicate safety performance than commonly used accident rates.

6.2. Future research considerations

Certain limitations of this study comprised of interesting research possibilities discussed in this section. As such, possible future research may utilise the findings and conclusions in a different light.

Safety investigations on smaller scale

This thesis focussed solely on the analysis of safety investigation reports as published by a state's safety investigation authority. These investigations are focussed on the improvements of safety and prevention of accidents and incidents in the aviation industry as a whole. This means that the most significant events are investigated on this level, and less severe or critical occurrences are investigated on a service provider's level. It was therefore discussed that the data compiled out of these safety investigation reports may comprise of different types of data (e.g. maintenance and ground operations) and trends that may differ from the overall industry safety performance. Also, the taxonomy's use is mainly aimed at the indication of safety performance, however, this has only been presented for the aggregate state level. Practicing this taxonomy on data of service providers might reveal strong variations and different applications of the taxonomy to present safety performance. Further research could therefore focus on a service provider level to demonstrate the practicability of the taxonomy.

Controllability taxonomy for different industries

Safety performance indicators are not only dedicated to aviation, or even transport industry for that matter. Each industry or institution that implicates human performance in the development of safety events may utilise this taxonomy to demonstrate its overall safety performance, areas of special attention and to drive resources and initiatives according this indication. Further research can thereby incorporate the applicability of the taxonomy in any industry that comprises possible control actions by involved personnel (e.g. transport, medical, nuclear).

Control in occurrence reporting scheme

As concluded in section 6.1, the prioritisation of investigative resources for incidents can be obtained with the controllability in such events. In order to obtain this, a new controllability field in occurrence reporting schemes can reveal the controllability of safety events without effort of safety investigation authorities and in much greater quantity, revealing trends in incident data. Although the possibility is mentioned, the practicability to implement such changes remains an open question. Changes to these schemes must be feasible, but also recognisable as an improvement worth the resources. That is, does this new implementation provide sufficient improvements to safety information to justify the time and expense? Implementation of this taxonomy in an occurrence reporting scheme can therefore be explored in future research.

6.3. Recommendations

As discussed before, the implementation of controllability in occurrence reporting schemes should be explored in further research. Therefore, it is recommended that the possibility and practicability of the control element in occurrence reporting schemes must be explored as this implementation may change the investigations in incidents drastically and more effectively.

Second, the use of the controllability taxonomy is found useful as safety performance indicator that demonstrates whether safety events were developed with a chance to control or were dependent on chance in which no control actions had effect on the outcome. Also, the distribution of control attempts can reveal a service provider's or an industry's effectiveness in alleviating such events. Areas that are found critical in controllability can be utilised to allocate resources and safety initiatives accordingly, rather than the common use of the severity of outcomes. Improvements in safety (performance) can be targeted at higher controlled by uncontrolled ratios and a higher ratio of positive by negative control attempts. It is therefore recommended that the use of this taxonomy could be applied to any industry or institution that seeks to unveil its safety performance in terms of controllability and drive resources accordingly to improve the overall safety.

A

Addendum

Contents

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Nederlandse samenvatting

Vandaag de dag is de luchtvaartindustrie is veiliger dan het ooit is geweest. Om echter zo'n uitspraak te doen gelden worden de uitkomsten van veiligheidsgebeurtenissen gebruikt om de veiligheidsprestaties (safety performance) te berekenen. Bovendien is het huidig aantal luchtvaartongevallen gedaald tot een significant laag niveau, waarbij veiligheid niet op een representatieve wijze uitgedrukt kan worden door middel van deze berekeningen. Veiligheidsgebeurtenissen worden meestal beïnvloed door de acties van het menselijke element, echter wordt dit onmiskenbare element in het ontstaan van ongevallen niet gebruikt in de berekening van veiligheid. Het is een nogal deterministische aanpak om veiligheid uit te drukken in negatieve uitkomsten, sinds het wellicht niet een realistisch beeld vertoont van het veiligheidsniveau van organisaties en de luchtvaartindustrie in het algemeen, omdat niet de controleerbaarheid meegenomen wordt in de berekening van veiligheid. Daarnaast worden onderzoeksmiddelen van veiligheidsonderzoek instanties toegewezen naar ongevallen gebaseerd op de ernst van de uitkomst van deze ongevallen die mede de omvang van het onderzoek bepaald. Ongevallen en ernstige incidenten worden vereist onderzocht te worden door deze instanties. Incidenten kunnen daarentegen betere informatie vergaren voor de preventie van ongevallen. Echter zijn incidenten niet vereist voor een onderzoek, noch zijn er voldoende middelen beschikbaar om alle incidenten te kunnen onderzoeken.

Een nieuwe taxonomie is gepubliceerd die de controleerbaarheid van een gebeurtenis meeneemt en beschouwt of deze (1) door de gebruiker controleert is, wat betekent dat er een kans bestond om in te grijpen in de ontwikkeling van de gebeurtenis en de uitkomst te verlichten, (2) deze neutraal door de gebruiker is gecontroleerd, de poging om te controleren had een reactionair karakter of was standaard procedure of (3) deze ongecontroleerd is, wat betekent dat er geen poging van de gebruiker is geweest en als resultaat ontwikkelde zonder interventie. Deze taxonomie werd gebruikt om een alternatieve benadering te presenteren, anders dan de huidige focus op negatieve uitkomsten, voor de indicatie van veiligheidsprestatie van veiligheidsinstanties. Ook werd gericht op het adequaat toewijzen van onderzoeksmiddelen gebaseerd op de geconstateerde problemen opgeroepen door de controleerbaarheid van ongevallen in plaats van de toewijzing die gebaseerd is op de impact door de ernst van een uitkomst. Zodanig kan wellicht de controleerbaarheid in veiligheidsprestaties meer representatief aangetoond worden en kan prioriteitscriteria gegeneerd worden om veiligheidsmiddelen adequater toe te wijzen over onderzoeken en daarmee beperkingen in bemanning te ondersteunen door prioriteitscriteria te genereren voor incidenten.

Deze studie paste de nieuwe taxonomie toe op 297 onderzoeksrapporten die verdeeld waren over vijf onderscheidde veiligheidsinstanties. De rapporten waren de enige bron van informatie aangezien het een nauwe relatie vormt met de verwachte praktische toepassing van de taxonomie: veiligheidsgebeurtenis informatie. Gebieden waar de taxonomie effectief toepasbaar is en juist niet goed toepasbaar is werd gezocht in de toepassing van de taxonomie, waarbij samenhangende factoren daarbij ook in verband onderzocht werden. Deze specifieke gebieden werden bepaald en ondersteund door wetenschappelijke literatuur en werd gevonden in de analyse van de samenhangende factoren in de controleerbaarheid van gebeurtenissen. Analysemethoden in deze studie omvatte frequentie, Chi-kwadraat en Spearman's rho analyses.

Het bleek dat de volgende factoren de controleerbaarheid beïnvloedde: nationaliteit verschillen van piloten, generatie van vliegtuigen, type operatie en de menselijke prestaties in verband met ervaring, rusttijden, werktijden en vermoeidheid. Er werden echter geen verschillen gevonden in de veranderingen van controleerbaarheid over tijd, die wel gezien worden in ongevallencijfers (accident rates). Veiligheidsonderzoeksinstanties bleken voorkeur te hebben voor de ernst van gebeurtenissen. Daarbij waren onderzoeken veel meer gericht op de gebeurtenissen die foute controleerpogingen bevatte, in plaatst van te focussen op gebeurtenissen die succes vertonen waar van geleerd kan worden. Met de kennis van de controleerbaarheid van een gebeurtenis kan prioriteitscriteria veiligheidsinstanties voorzien van informatie om onderzoeksmiddelen te positioneren op basis van de controleerbaarheid en meer gelijkmatig te verdelen over de klassen van controleerbaarheden. Ongevallen en ernstige incidenten zijn verplicht onderzocht te worden, waarbij de toepassing van informatie over de controleerbaarheid gebruikt kan worden de onderzoeksmiddelen effectiever te beheren. Daarbij is een klein onderzoek vereist voor de verkrijging van deze informatie.

Anderzijds zijn incident nier verplicht onderzocht te worden en door beperkingen in onderzoeksmiddelen niet zo vaak of zo grondig onderzocht als ongevallen of ernstige incidenten. Het verkrijgen van de controleerbaarheid van incidenten bestond uit twee opties: (1) een klein onderzoek en (2) het melden van voorvallen door betrokkenen. Dit eerste kleine onderzoek is identiek aan die van ongevallen en ernstige incidenten;

het vergt enige inspanning van de veiligheidsinstantie om de informatie op te halen. De tweede optie is gebaseerd op de levende getuigen. Het implementeren van een "controleerbaarheids-" veld in rapporten voor de melding van voorvallen maakt het mogelijk om incidenten te selecteren en onderzoeksmiddelen hierop te prioriteren, zonder extra inspanning. Bovendien, in een gemeenschappelijk geaccepteerd veld in meldingsrapporten, kan de grotere hoeveelheid aan data trends openbaren en gebieden aanduiden die extra aandacht vereisen dat vervolgens kan bijdragen aan de toewijzing van onderzoeksmiddelen op deze specifieke gebieden. De selectie van de incidenten was gericht op het zeldzame karakter van een controleerbaarheidsklasse. De ongecontroleerde klasse was bevonden van deze aard. Onderzoeken naar de andere controleerbaarheidsklassen zijn belangrijk, echter kunnen deze ook gevonden en onderzocht worden in het verplichte onderzoeken. Deze zeldzame ongecontroleerde incidenten moeten dus geprioriteerd worden voor incidenten onderzoeken. Dat wil zeggen, een veiligheidsinstantie moet een onderzoek in ongecontroleerde incidenten uit voeren wanneer ze voorgesteld worden met één.

De taxonomie geeft aan of gebeurtenissen afhankelijk waren van toeval, aangegeven door ongecontroleerde gebeurtenissen, of bestaat uit potentiele controleerbaarheid in de interventie van ontwikkelende gebeurtenissen. Het kan daarbij ook gebruikt worden om de effectiviteit van controle aan te tonen om de doeltreffendheid van personeel aan te tonen. De samenhangende factoren hierbij kunnen aantonen welke gebieden extra aandacht vereisen om de veiligheid meer gericht te verbeteren. Daarnaast was bevonden dat in een periode van 25 jaar geen veranderingen plaatsvonden voor de controleerbaarheid in gebeurtenissen, terwijl verbeteringen in veiligheid wordt geclaimd voor dezelfde periode door middel van ongevallencijfers. Om de veiligheid vervolgens te verbeteren door middel van de controleerbaarheidstaxonomie, zullen streefwaarden ingesteld moeten worden op hogere verhoudingen van gecontroleerde tot ongecontroleerde gebeurtenissen en positieve tot negatieve controle pogingen. Met al het bovengenoemde kan geconstateerd worden dat veiligheidsprestaties met de controleerbaarheid van gebeurtenissen als een meer representatieve en effectieve manier omvat om de veiligheid prestaties aan te tonen dan de gebruikelijke ongevallencijfers.

Tot slot is het aanbevolen de mogelijke implementatie van de controleerbaarheid van gebeurtenissen in meldingsrapporten verder te onderzoeken. Deze implementatie kan het selecteren van incidenten voor onderzoeken drastisch en op een effectieve wijze aanpassen, aangezien hiermee trends en kritieke gebieden aangetoond kunnen worden voor de gehele industrie. Het is daarbij verder aanbevolen voor elke sector of instelling die ernaar streeft de veiligheidsprestaties aan te tonen door middel van de controleerbaarheid van gebeurtenissen en daarbij de onderzoeksmiddelen hierop af te stemmen wordt aangemoedigd om de taxonomie te implementeren.

Appendix I *Dependent and independent variables of the study*

Table i: All dependent variables of the study

Designator	Dependent variables
1	Accident control classes
2	Control attempt effectiveness
3	Length safety investigation report

Note. The dependent variables are classified by a designator that is employed in the table below to indicate which independent variables are analysed with respect to the dependent variables.

Independent variables	Dependent variables
Safety investigation authority	1,2
Continent of occurrence	1,2
Region of occurrence	1,2
Country of occurrence	1,2
Continent of origin	1,2
Region of origin	1,2
Country of origin	1,2
Year of the occurrence	1,2
Month of the occurrence	1,2
Season of the occurrence	1,2
Time of day at the occurrence	1,2
Age of the aircraft at the occurrence	1,2,3
Type of aircraft of the occurrence	1,2,3
Weight class of the aircraft of the occurrence	1,2,3
Type of flight of the occurrence	1,2,3
Type of flight sub-category of the occurrence	1,2,3
Flight phase at the occurrence	1,2
Category of the occurrence	1,2,3
Classification of the occurrence	1,2,3
Severity class of the occurrence	1,2,3
Number of fatal injuries with the occurrence	1,2,3
Number of serious injuries with the occurrence	1,2,3
Number of minor and no injuries with the occurrence	1,2,3
Age of respective controller*	1,2
Type specific experience of respective controller*	1,2
All type experience of respective controller*	1,2
Time on duty of respective controller*	1,2
Sleep period prior start duty of respective controller*	1,2
Rest period prior start duty of respective controller*	1,2
Fatigue as contributory factor	1,2
Length of safety investigation reports**	1,2

* The “respective” controller implies that the same data to be recorded and analysed for all concerned controllers with respect to the dependent variables.
** The length of safety investigation reports was additionally employed as independent variable for dependentvariables 1 and 2.
Note. See Table 1 for reference of the dependent variables.

Appendix IIa *Frequency analysis results*

Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
Safety Investigation Authority		
AAIBUK	73	23
ATSB	41	12,9
DUTCHSB	68	21,4
NTSB	75	23,6
TSBCAN	61	19,2
Total	318	100

Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
Occurrence location - Continent		
Africa	1	0,3
Asia	4	1,3
Australia	37	11,6
Europe	131	41,2
International waters	5	1,6
North America	139	43,7
Oceania	1	0,3
Total	318	100

	Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
	Occurrence location - Region		
	APAC	42	13,2
	EUR	135	42,6
	PA	140	44,2
	Total	317	100
Missing	AFI	1	

Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
Occurrence location - Country		
Afghanistan	1	0,3
Australia	37	11,6
Canada	60	18,9
Channel Islands	6	1,9
China	1	0,3
Dominican Republic	1	0,3
Germany	1	0,3
International waters	10	3,1
Marshall Islands	1	0,3
Netherlands	66	20,8
Puerto Rico	1	0,3
Saint Kitts and Nevis	1	0,3
Sudan	1	0,3
Thailand	1	0,3
Timor-Leste	1	0,3
Turks and Caicos Islands	2	0,6
United Kingdom	55	17,3
USA	72	22,6

	Total	318	100

	Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
	Operator nationality - Continent		
	Africa	4	1,3
	Asia	9	2,9
	Australia	36	11,6
	Europe	118	38,1
	North America	141	45,5
	Oceania	2	0,6
	Total	310	100
Missing	UNKN	8	

	Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
	Operator nationality - Region		
	APAC	45	14,8
	EUR	118	38,8
	PA	141	46,4
	Total	304	100
Missing	AFI	4	
	MID	2	
	UNKN	8	

Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
Operator nationality - Country		
Australia	36	11,6
Belgium	2	0,6
Canada	56	18,1
Cape Verde	1	0,3
Channel Islands	1	0,3
China	1	0,3
Denmark	2	0,6
Fiji	1	0,3
France	1	0,3
Germany	4	1,3
Iran	2	0,6
Ireland	1	0,3
Italy	1	0,3
Japan	2	0,6
Jordan	1	0,3
Korea	1	0,3
Loa People's Democratic Republic	1	0,3
Marrocco	1	0,3
Morocco	1	0,3
Netherlands	31	10
New Zealand	1	0,3
Nigeria	1	0,3
Puerto Rico	1	0,3
Russia	1	0,3
South Korea	1	0,3
Spain	2	0,6
Switzerland	1	0,3
Turkey	6	1,9

	Turks and Caicos Islands	1	0,3
	United Kingdom	65	21
	USA	83	26,8
	Total	310	100
Missing	UNKN	8	

Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
Year of occurrence		
1990	1	0,3
1991	1	0,3
1994	10	3,1
1995	8	2,5
1996	14	4,4
1997	15	4,7
1998	10	3,1
1999	8	2,5
2000	8	2,5
2001	12	3,8
2002	12	3,8
2003	17	5,3
2004	15	4,7
2005	28	8,8
2006	24	7,5
2007	19	6
2008	21	6,6
2009	23	7,2
2010	14	4,4
2011	16	5
2012	16	5
2013	16	5
2014	10	3,1
Total	318	100

Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
Season of occurrence		
Autumn	67	21,1
Spring	67	21,1
Summer	94	29,6
Winter	90	28,3
Total	318	100

	Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
	Daytime at occurrence		
	Afternoon	122	40,3
	Evening	71	23,4
	Morning	94	31
	Night	16	5,3
	Total	303	100
Missing	UNKN	15	

Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
Type of aircraft		
Glider	2	0,6
Jet	152	47,8
Propellor	116	36,5
Rotary	45	14,2

	UNKN	3	0,9
	Total	318	100

	Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
	Weight class of aircraft		
	>272000	23	7,3
	0-2250	68	21,6
	2251-5700	54	17,1
	27001-272000	111	35,2
	5701-27000	59	18,7
	Total	315	100
Missing	UNKN	3	

	Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
	Flight type		
	Aerial Work (AW)	17	5,5
	Commercial Air Transport (CAT)	223	72,6
	General Aviation (GA)	64	20,8
	State flights (SF)	3	1
	Total	307	100
Missing	UNKN	11	

	Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
	Flight type subcategory		
	AW-Commercial	11	3,6
	AW-Non Commercial	5	1,7
	CAT-NonRevenue Ferry/ positioning	9	3
	CAT-NonRevenue Flying Displays	1	0,3
	CAT-NonRevenue Other	2	0,7
	CAT-NonRevenue Post Maintenance check flight	5	1,7
	CAT-Other	20	6,6
	CAT-Revenue Cargo flight	25	8,3
	CAT-Revenue Passenger flight	158	52,1
	GA-Business	6	2
	GA-Flight training/ instructional	17	5,6
	GA-Other	5	1,7
	GA-Pleasure	36	11,9
	SF-Coast guard	2	0,7
	SF-Military	1	0,3
	Total	303	100
Missing	UNKN	15	

Independent variables	Frequency distribution Absolute Frequency	Relative frequency (%)
Flight phase		
Approach	59	18,6
Cruise	79	24,8
Descent	13	4,1
Engine	3	0,9
Enroute climb	4	1,3

Go-Around	6	1,9
Initial Climb	19	6
Landing	47	14,8
Pre flight	2	0,6
RTO	6	1,9
Take Off	70	22
Taxi Out	7	2,2
Taxi-in	3	0,9
Total	318	100

Independent variables	Frequency distribution	
	Absolute Frequency	Relative frequency (%)
Occurrence category		
ADRM	10	3,1
ARC	17	5,3
ATM	6	1,9
BIRD	3	0,9
CABIN	2	0,6
CFIT	23	7,2
CTOL	11	3,5
EVAC	1	0,3
EXTL	2	0,6
F-NI	14	4,4
FUEL	7	2,2
LALT	1	0,3
LOC-I	47	14,8
LOLI	2	0,6
MAC	33	10,4
OTHR	5	1,6
RAMP	3	0,9
RE	22	6,9
RI	10	3,1
SCF-NP	39	12,3
SCF-PP	49	15,4
TURB	3	0,9
UIMC	3	0,9
USOS	4	1,3
WSTRW	1	0,3
Total	318	100

Independent variables	Frequency distribution	
	Absolute Frequency	Relative frequency (%)
Occurrence classification		
Accident	204	64,2
Incident	48	15,1
Serious incident	66	20,8
Total	318	100

Independent variables	Frequency distribution	
	Absolute Frequency	Relative frequency (%)
Occurrence severity		
A	138	43,4
B	18	5,7
C	81	25,5
D	63	19,8
E	18	5,7
Total	318	100

Appendix IIb *Frequency analysis resulting groupings of independent variables*

Independent variables	Grouping of variables						
	1	2	3	4	5	6	7
Occurrence location - Continent	Australia (12.1%)	Europe (42.7%)	North America (45.3%)				
Occurrence location - Region	APAC (13.2%)	EUR (42.6%)	PA (44.2%)				
Occurrence location - Country	Australia (11.6%)	Canada (18.9%)	Netherlands (20.8%)	Other (8.8%)	United Kingdom (17.3%)	USA (22.6%)	
Operator nationality - Continent	Australia (12.2%)	Europe (40.0%)	North America (47.8%)				
Operator nationality - Region	APAC (14.8%)	EUR (38.8%)	PA (46.4%)				
Operator nationality - Country	Australia (11.6%)	Canada (18.1%)	Netherlands (10.0%)	Other (12.6%)	United Kingdom (21.0%)	USA (26.8%)	
Year of occurrence	1990-1999 (21.1%)	2000-2005 (28.9%)	2006-2009 (27.4%)	2010-2014 (22.6%)			
Age of aircraft	0-6 (25.5%)	15-24 (24.8%)	7 -14 (25.2%)	Over 25 (24.5%)			
Type of aircraft	Jet (48.6%)	Propellor (37.1%)	Rotary (14.4%)				
Weight class of aircraft	>27001 (42.5%)	0-27000 (57.5%)					
Flight type	Commercial Air Transport (CAT) (72.6%)	Other (27.4%)					
Flight type subcategory	Non-passenger (45.9%)	Passenger (54.1%)					
Flight phase	En-route (30.2%)	Ground (28.6%)	Other flight phases (41.2%)				
Occurrence category	CFIT (7.2%)	LOC-I (14.8%)	MAC (10.4%)	Other (33.0%)	RE (6.9%)	SCF-NP (39.0%)	SCF-PP (15.4%)
Occurrence severity	A (44.4%)	BC (31.1%)	DE (25.5%)				
Fatal injuries	No (61.4%)	Yes (38.6%)					
Serious injuries	No (85.1%)	Yes (14.9%)					
Minor injuries	No (36.0%)	Yes (64.0%)					
Controller 1 - Age	≤ 42 (39.0%)	≥ 43 (61.0%)					
Controller 1 - Type rating exp.	≤ 1000 (44.8%)	≥ 1001 (55.2%)					
Controller 1 - All time exp.	≤ 5200 (41.7%)	≥ 5201 (58.3%)					
Controller 2 - Age	≤ 42 (71.2%)	≥ 43 (28.8%)					
Controller 2 - Type rating exp.	≤ 1000 (59.3%)	≥ 1001 (40.7%)					

Independent variables	Grouping of variables						
	1	2	3	4	5	6	7
Controller 2 - All time exp.	≤ 5200 (63.3%)	≥ 5201 (36.7%)					
Controller 1 - Sleep period prior	>=8 (71.4%)	>9 (28.6%)					
Controller 2 - Sleep period prior	>=8 (60.9%)	>9 (39.1%)					
Controller 1 - Duty time	<=5 (57.3%)	>5 (42.7%)					
Controller 1 - Rest period	<=19 (56.3%)	>19 (43.8%)					
Controller 2 - Duty time	<=5 (53.2%)	>5 (46.8%)					
Controller 2 - Rest period	<=19 (48.8%)	>19 (51.2%)					
Fatigue	No (90.3%)	Yes (9.7%)					
Report total word count	≤ 2.500 (25.2%)	≥ 24.000 (25.2%)	10.001 - 24.000 (25.5%)	2.501 - 10.000 (25.2%)			
Factual section word count	≤ 1.300 (24.8%)	≥ 15.301 (25.2%)	1.301 - 6.000 (24.5%)	6.001 - 15.300 (25.5%)			
Analysis section word count	≤ 690 (24.8%)	≥ 7.701 (25.2%)	2.601 - 7.700 (24.5%)	691 - 2.600 (25.5%)			
Conclusion section word count	≤ 180 (24.8%)	≥ 901 (25.8%)	181 - 440 (25.2%)	441 - 900 (24.2%)			
Recommendation section word count	≥ 471 (29.2%)	0 (25.5%)	1 - 470 (45.3%)				
Amount of recommendations	≥ 7 (25.2%)	0 (44.0%)	1 - 6 (30.8%)				

Appendix III *Temporal factors Chi-square test results*

Table i: Temporal factors with respect to the accident control classes and outcome control attempt effectiveness in terms of a percentage distribution.

Independent variables	**Accident control classes**			**Outcome control attempt**	
	Controlled (%)	Neutral (%)	Uncontrolled (%)	Positive (%)	Negative (%)
Year					
1990-1999	52.2	29.9	17.9	45.7	54.3
2000-2005	53.8	24.2	22.0	40.8	59.2
2006-2009	49.4	19.5	31.0	47.7	52.3
2010-2014	48.6	26.4	25.0	34.3	65.7
Season					
Winter	53.3	24.4	22.2	47.9	52.1
Spring	56.1	21.2	22.7	27.0	73.0
Summer	43.6	27.7	28.7	53.7	46.3
Autumn	53.7	23.9	22.4	37.8	62.2
Daytime					
Morning	45.7	24.5	29.8	46.5	53.5
Afternoon	50.4	27.3	22.3	35.5	64.5
Evening	56.3	19.7	23.9	50.0	50.0
Night	62.5	12.5	25.0	50.0	50.0

Appendix IV *Report length on accident control classes results of Chi-square test*

Table ii: Safety investigation reports categorised extent for the accident control classes and control attempt effectiveness in terms of a percentage distribution.

Independent variables	**Accident control classes**			**Outcome control attempt**	
	Controlled (%)	Neutral (%)	Uncontrolled (%)	Positive (%)	Negative (%)
Total word count					
≤ 2.500	43.8	31.3	25.0	83.3	16.7
2.501 - 10.000	43.0	30.4	26.6	64.7	35.3
10.001 - 24.000	51.3	20.5	28.2	57.5	42.5
≥ 24.000	66.3	16.3	17.5	35.8	64.2
Factual section					
≤ 1.300	43.0	30.4	26.6	82.4	17.6
1.301 - 6.000	46.8	26.0	27.3	64.9	35.1
6.001 - 15.300	45.7	25.9	28.4	54.1	45.9
≥ 15.301	68.8	16.3	15.0	40.0	60.0
Analysis section					
≤ 690	41.8	34.2	24.1	82.4	17.6
690 - 2.600	45.0	23.8	31.3	75.0	25.0
2.601 - 7.700	56.4	23.1	20.5	52.3	47.7
≥ 7.701	61.3	17.5	21.3	32.7	67.3
Conclusion section					
≤ 180	42.3	29.5	28.2	82.4	17.6
181 - 440	43.8	26.3	30.0	71.4	28.6
441 - 900	61.0	16.9	22.1	40.4	59.6
≥ 901	57.3	25.6	17.1	53.2	46.8
Recommendation section					
0	45.7	21.0	33.3	81.6	18.4
1 - 470	47.9	31.9	20.1	55.1	44.9
≥ 471	60.9	16.3	22.8	44.6	55.4
Number of recommendations					
0	43.9	29.5	26.6	82.3	17,7
1 - 6	51.0	25.5	23.5	46.0	54.0
≥ 7	63.8	15.0	21.3	39.2	60.8

Appendix V *Chi-square test for length in all report sections*

Table iii: Chi-square analysis results for the length of safety investigation reports per considered section with respect to aircraft and flight specifics and occurrence details.

Independent variables	Total words		Factual		Analysis		Conclusion		Recommendation		Number of recommendations	
	$\chi2$[a]	*P*[b]	$\chi2$	*P*	$\chi2$	*P*	$\chi2$	*P*	$\chi2$	*P*	$\chi2$	*P*
Aircraft and flight specifics												
Aircraft Type	9,334	0.156	9,698	0.138	13,087	**0.042**	20,535	**0.002**	9,218	0.056	11,082	**0.026**
Aircraft weight	4,436	0.218	3,77	0.287	4,99	0.173	10,1	**0.018**	7,974	**0.019**	5,001	0.082
Flight type	8,916	**0.042***	12,319	**0.006**	8,229	**0.042**	14,811	**0.002**	11,384	**0.003**	7,21	**0.027**
Flight sub type	2,704	0.440	2,178	0.536	2,589	0.459	3,317	0.345	5,88	0.053	2,859	0.239
Occurrence details												
Occurrence cat	36,621	**0.006**	41,862	**0.001**	15,597	0.621	17,686	0.477	16,054	0.189	10,089	0.608
Occurrence type	59,749	**0.000**	61,424	**0.000**	48,797	**0.000**	27,975	**0.000**	47,922	**0.000**	42,812	**0.000**
Occurrence severity	58,854	**0.000**	48,061	**0.000**	47,962	**0.000**	21,129	**0.002**	52,584	**0.000**	47,577	**0.000**
Fatal injuries	41,948	**0.000**	42,795	**0.000**	36,159	**0.000**	19,395	**0.000**	43,26	**0.000**	36,581	**0.000**
Serious injuries	28,655	**0.000**	17,246	**0.001**	14,757	**0.002**	7,973	**0.047**	12,722	**0.002**	7,08	**0.029**
Minor injuries	23,05	**0.000**	21,749	**0.000**	19,153	**0.000**	11,232	**0.011**	28,294	**0.000**	20,497	**0.000**

[a] $\chi2$ represents the Pearson's Chi-square value
[b] P stands for the signficance of the Chi-square test

Note: All results from the statistical Chi-square analysis are presented and do not all represent significant data.
* Bold type and underlined represents a significance of $P < 0.05$

Appendix VI *Occurrence severity and region of origin multivariate Chi-square test*

Crosstab								
ORREG				REPTOTALB				Total
				≤ 2.500	≥ 24.000	10.001 - 24.000	2.501 - 10.000	
APAC	OCSEVB	A	Count	1	7	3	1	12
			% within OCSEVB	8,3%	58,3%	25,0%	8,3%	100,0%
			% within REPTOTALB	5,0%	100,0%	50,0%	8,3%	26,7%
			% of Total	2,2%	15,6%	6,7%	2,2%	26,7%
		BC	Count	10	0	2	7	19
			% within OCSEVB	52,6%	0,0%	10,5%	36,8%	100,0%
			% within REPTOTALB	50,0%	0,0%	33,3%	58,3%	42,2%
			% of Total	22,2%	0,0%	4,4%	15,6%	42,2%
		DE	Count	9	0	1	4	14
			% within OCSEVB	64,3%	0,0%	7,1%	28,6%	100,0%
			% within REPTOTALB	45,0%	0,0%	16,7%	33,3%	31,1%
			% of Total	20,0%	0,0%	2,2%	8,9%	31,1%
	Total		Count	20	7	6	12	45
			% within OCSEVB	44,4%	15,6%	13,3%	26,7%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	44,4%	15,6%	13,3%	26,7%	100,0%
EUR	OCSEVB	A	Count	3	9	13	5	30
			% within OCSEVB	10,0%	30,0%	43,3%	16,7%	100,0%
			% within REPTOTALB	9,1%	52,9%	30,2%	20,0%	25,4%
			% of Total	2,5%	7,6%	11,0%	4,2%	25,4%
		BC	Count	17	6	12	8	43
			% within OCSEVB	39,5%	14,0%	27,9%	18,6%	100,0%
			% within REPTOTALB	51,5%	35,3%	27,9%	32,0%	36,4%
			% of Total	14,4%	5,1%	10,2%	6,8%	36,4%
		DE	Count	13	2	18	12	45
			% within OCSEVB	28,9%	4,4%	40,0%	26,7%	100,0%
			% within REPTOTALB	39,4%	11,8%	41,9%	48,0%	38,1%
			% of Total	11,0%	1,7%	15,3%	10,2%	38,1%
	Total		Count	33	17	43	25	118
			% within OCSEVB	28,0%	14,4%	36,4%	21,2%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	28,0%	14,4%	36,4%	21,2%	100,0%
PA	OCSEVB	A	Count	11	43	20	18	92
			% within OCSEVB	12,0%	46,7%	21,7%	19,6%	100,0%
			% within REPTOTALB	45,8%	78,2%	80,0%	48,6%	65,2%
			% of Total	7,8%	30,5%	14,2%	12,8%	65,2%
		BC	Count	7	12	2	12	33
			% within OCSEVB	21,2%	36,4%	6,1%	36,4%	100,0%
			% within REPTOTALB	29,2%	21,8%	8,0%	32,4%	23,4%
			% of Total	5,0%	8,5%	1,4%	8,5%	23,4%

Crosstab								
ORREG				REPTOTALB				Total
				≤ 2.500	≥ 24.000	10.001 - 24.000	2.501 - 10.000	
PA	OCSEVB	DE	Count	6	0	3	7	16
			% within OCSEVB	37,5%	0,0%	18,8%	43,8%	100,0%
			% within REPTOTALB	25,0%	0,0%	12,0%	18,9%	11,3%
			% of Total	4,3%	0,0%	2,1%	5,0%	11,3%
	Total		Count	24	55	25	37	141
			% within OCSEVB	17,0%	39,0%	17,7%	26,2%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	17,0%	39,0%	17,7%	26,2%	100,0%
Total	OCSEVB	A	Count	15	59	36	24	134
			% within OCSEVB	11,2%	44,0%	26,9%	17,9%	100,0%
			% within REPTOTALB	19,5%	74,7%	48,6%	32,4%	44,1%
			% of Total	4,9%	19,4%	11,8%	7,9%	44,1%
		BC	Count	34	18	16	27	95
			% within OCSEVB	35,8%	18,9%	16,8%	28,4%	100,0%
			% within REPTOTALB	44,2%	22,8%	21,6%	36,5%	31,3%
			% of Total	11,2%	5,9%	5,3%	8,9%	31,3%
		DE	Count	28	2	22	23	75
			% within OCSEVB	37,3%	2,7%	29,3%	30,7%	100,0%
			% within REPTOTALB	36,4%	2,5%	29,7%	31,1%	24,7%
			% of Total	9,2%	,7%	7,2%	7,6%	24,7%
	Total		Count	77	79	74	74	304
			% within OCSEVB	25,3%	26,0%	24,3%	24,3%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	25,3%	26,0%	24,3%	24,3%	100,0%

Note. Certain abbreviations are used in the statistical computation: APAC is Asia Pacific; EUR is Europe; PA is Pan America; ORREG stands for region of origin; OCSEVB stands for occurrence severity classification; REPORTOTALB stands for the word classification of safety investigation reports.

Appendix VII *Occurrence severity and country of origin multivariate Chi-square test*

Crosstab								
ORCOUNTB				REPTOTALB				Total
				≤ 2.500	≥ 24.000	10.001 - 24.000	2.501 - 10.000	
Australia	OCSEVB	A	Count	1	4	3	1	9
			% within OCSEVB	11,1%	44,4%	33,3%	11,1%	100,0%
			% within REPTOTALB	5,9%	100,0%	60,0%	10,0%	25,0%
			% of Total	2,8%	11,1%	8,3%	2,8%	25,0%
		BC	Count	8	0	2	6	16
			% within OCSEVB	50,0%	0,0%	12,5%	37,5%	100,0%
			% within REPTOTALB	47,1%	0,0%	40,0%	60,0%	44,4%
			% of Total	22,2%	0,0%	5,6%	16,7%	44,4%
		DE	Count	8	0	0	3	11
			% within OCSEVB	72,7%	0,0%	0,0%	27,3%	100,0%
			% within REPTOTALB	47,1%	0,0%	0,0%	30,0%	30,6%
			% of Total	22,2%	0,0%	0,0%	8,3%	30,6%
	Total		Count	17	4	5	10	36
			% within OCSEVB	47,2%	11,1%	13,9%	27,8%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	47,2%	11,1%	13,9%	27,8%	100,0%
Canada	OCSEVB	A	Count	10	2	0	16	28
			% within OCSEVB	35,7%	7,1%	0,0%	57,1%	100,0%
			% within REPTOTALB	47,6%	100,0%	0,0%	50,0%	50,0%
			% of Total	17,9%	3,6%	0,0%	28,6%	50,0%
		BC	Count	6	0	0	11	17
			% within OCSEVB	35,3%	0,0%	0,0%	64,7%	100,0%
			% within REPTOTALB	28,6%	0,0%	0,0%	34,4%	30,4%
			% of Total	10,7%	0,0%	0,0%	19,6%	30,4%
		DE	Count	5	0	1	5	11
			% within OCSEVB	45,5%	0,0%	9,1%	45,5%	100,0%
			% within REPTOTALB	23,8%	0,0%	100,0%	15,6%	19,6%
			% of Total	8,9%	0,0%	1,8%	8,9%	19,6%
	Total		Count	21	2	1	32	56
			% within OCSEVB	37,5%	3,6%	1,8%	57,1%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	37,5%	3,6%	1,8%	57,1%	100,0%
Netherlands	OCSEVB	A	Count	1	0	0	3	4
			% within OCSEVB	25,0%	0,0%	0,0%	75,0%	100,0%
			% within REPTOTALB	5,9%	0,0%	0,0%	25,0%	12,9%
			% of Total	3,2%	0,0%	0,0%	9,7%	12,9%
		BC	Count	11	0	2	4	17
			% within OCSEVB	64,7%	0,0%	11,8%	23,5%	100,0%
			% within REPTOTALB	64,7%	0,0%	100,0%	33,3%	54,8%
			% of Total	35,5%	0,0%	6,5%	12,9%	54,8%

Crosstab								
ORCOUNTB				REPTOTALB				Total
				≤ 2.500	≥ 24.000	10.001 - 24.000	2.501 - 10.000	
Netherlands	OCSEVB	DE	Count	5	0	0	5	10
			% within OCSEVB	50,0%	0,0%	0,0%	50,0%	100,0%
			% within REPTOTALB	29,4%	0,0%	0,0%	41,7%	32,3%
			% of Total	16,1%	0,0%	0,0%	16,1%	32,3%
	Total		Count	17	0	2	12	31
			% within OCSEVB	54,8%	0,0%	6,5%	38,7%	100,0%
			% within REPTOTALB	100,0%	0,0%	100,0%	100,0%	100,0%
			% of Total	54,8%	0,0%	6,5%	38,7%	100,0%
Other	OCSEVB	A	Count	2	4	1	1	8
			% within OCSEVB	25,0%	50,0%	12,5%	12,5%	100,0%
			% within REPTOTALB	13,3%	80,0%	10,0%	11,1%	20,5%
			% of Total	5,1%	10,3%	2,6%	2,6%	20,5%
		BC	Count	7	1	6	3	17
			% within OCSEVB	41,2%	5,9%	35,3%	17,6%	100,0%
			% within REPTOTALB	46,7%	20,0%	60,0%	33,3%	43,6%
			% of Total	17,9%	2,6%	15,4%	7,7%	43,6%
		DE	Count	6	0	3	5	14
			% within OCSEVB	42,9%	0,0%	21,4%	35,7%	100,0%
			% within REPTOTALB	40,0%	0,0%	30,0%	55,6%	35,9%
			% of Total	15,4%	0,0%	7,7%	12,8%	35,9%
	Total		Count	15	5	10	9	39
			% within OCSEVB	38,5%	12,8%	25,6%	23,1%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	38,5%	12,8%	25,6%	23,1%	100,0%
United kingdom	OCSEVB	A	Count	0	8	13	2	23
			% within OCSEVB	0,0%	34,8%	56,5%	8,7%	100,0%
			% within REPTOTALB	0,0%	50,0%	35,1%	25,0%	35,4%
			% of Total	0,0%	12,3%	20,0%	3,1%	35,4%
		BC	Count	1	6	7	2	16
			% within OCSEVB	6,3%	37,5%	43,8%	12,5%	100,0%
			% within REPTOTALB	25,0%	37,5%	18,9%	25,0%	24,6%
			% of Total	1,5%	9,2%	10,8%	3,1%	24,6%
		DE	Count	3	2	17	4	26
			% within OCSEVB	11,5%	7,7%	65,4%	15,4%	100,0%
			% within REPTOTALB	75,0%	12,5%	45,9%	50,0%	40,0%
			% of Total	4,6%	3,1%	26,2%	6,2%	40,0%
	Total		Count	4	16	37	8	65
			% within OCSEVB	6,2%	24,6%	56,9%	12,3%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	6,2%	24,6%	56,9%	12,3%	100,0%

Crosstab								
ORCOUNTB				REPTOTALB				Total
				≤ 2.500	≥ 24.000	10.001 - 24.000	2.501 - 10.000	
United States of America	OCSEVB	A	Count	1	41	19	2	63
			% within OCSEVB	1,6%	65,1%	30,2%	3,2%	100,0%
			% within REPTOTALB	33,3%	77,4%	86,4%	40,0%	75,9%
			% of Total	1,2%	49,4%	22,9%	2,4%	75,9%
		BC	Count	1	12	1	1	15
			% within OCSEVB	6,7%	80,0%	6,7%	6,7%	100,0%
			% within REPTOTALB	33,3%	22,6%	4,5%	20,0%	18,1%
			% of Total	1,2%	14,5%	1,2%	1,2%	18,1%
		DE	Count	1	0	2	2	5
			% within OCSEVB	20,0%	0,0%	40,0%	40,0%	100,0%
			% within REPTOTALB	33,3%	0,0%	9,1%	40,0%	6,0%
			% of Total	1,2%	0,0%	2,4%	2,4%	6,0%
	Total		Count	3	53	22	5	83
			% within OCSEVB	3,6%	63,9%	26,5%	6,0%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	3,6%	63,9%	26,5%	6,0%	100,0%
Total	OCSEVB	A	Count	15	59	36	25	135
			% within OCSEVB	11,1%	43,7%	26,7%	18,5%	100,0%
			% within REPTOTALB	19,5%	73,8%	46,8%	32,9%	43,5%
			% of Total	4,8%	19,0%	11,6%	8,1%	43,5%
		BC	Count	34	19	18	27	98
			% within OCSEVB	34,7%	19,4%	18,4%	27,6%	100,0%
			% within REPTOTALB	44,2%	23,8%	23,4%	35,5%	31,6%
			% of Total	11,0%	6,1%	5,8%	8,7%	31,6%
		DE	Count	28	2	23	24	77
			% within OCSEVB	36,4%	2,6%	29,9%	31,2%	100,0%
			% within REPTOTALB	36,4%	2,5%	29,9%	31,6%	24,8%
			% of Total	9,0%	,6%	7,4%	7,7%	24,8%
	Total		Count	77	80	77	76	310
			% within OCSEVB	24,8%	25,8%	24,8%	24,5%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	24,8%	25,8%	24,8%	24,5%	100,0%

Note. Certain abbreviations are used in the statistical computation: ORCOUNTB stands for country of origin (or nationality); OCSEVB stands for occurrence severity classification; REPORTOTALB stands for the word classification of safety investigation reports.

Appendix VIII *Occurrence classes and region of origin Multivariate Chi-square test*

Crosstab								
ORREG				REPTOTALB				Total
				≤ 2.500	≥ 24.000	10.001 - 24.000	2.501 - 10.000	
APAC	OCTYPE	Accident	Count	5	7	3	5	20
			% within OCTYPE	25,0%	35,0%	15,0%	25,0%	100,0%
			% within REPTOTALB	25,0%	100,0%	50,0%	41,7%	44,4%
			% of Total	11,1%	15,6%	6,7%	11,1%	44,4%
		Incident	Count	10	0	1	5	16
			% within OCTYPE	62,5%	0,0%	6,3%	31,3%	100,0%
			% within REPTOTALB	50,0%	0,0%	16,7%	41,7%	35,6%
			% of Total	22,2%	0,0%	2,2%	11,1%	35,6%
		Serious incident	Count	5	0	2	2	9
			% within OCTYPE	55,6%	0,0%	22,2%	22,2%	100,0%
			% within REPTOTALB	25,0%	0,0%	33,3%	16,7%	20,0%
			% of Total	11,1%	0,0%	4,4%	4,4%	20,0%
	Total		Count	20	7	6	12	45
			% within OCTYPE	44,4%	15,6%	13,3%	26,7%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	44,4%	15,6%	13,3%	26,7%	100,0%
EUR	OCTYPE	Accident	Count	11	14	22	11	58
			% within OCTYPE	19,0%	24,1%	37,9%	19,0%	100,0%
			% within REPTOTALB	33,3%	82,4%	51,2%	44,0%	49,2%
			% of Total	9,3%	11,9%	18,6%	9,3%	49,2%
		Incident	Count	4	1	6	5	16
			% within OCTYPE	25,0%	6,3%	37,5%	31,3%	100,0%
			% within REPTOTALB	12,1%	5,9%	14,0%	20,0%	13,6%
			% of Total	3,4%	,8%	5,1%	4,2%	13,6%
		Serious incident	Count	18	2	15	9	44
			% within OCTYPE	40,9%	4,5%	34,1%	20,5%	100,0%
			% within REPTOTALB	54,5%	11,8%	34,9%	36,0%	37,3%
			% of Total	15,3%	1,7%	12,7%	7,6%	37,3%
	Total		Count	33	17	43	25	118
			% within OCTYPE	28,0%	14,4%	36,4%	21,2%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	28,0%	14,4%	36,4%	21,2%	100,0%
PA	OCTYPE	Accident	Count	16	55	22	27	120
			% within OCTYPE	13,3%	45,8%	18,3%	22,5%	100,0%
			% within REPTOTALB	66,7%	100,0%	88,0%	73,0%	85,1%
			% of Total	11,3%	39,0%	15,6%	19,1%	85,1%
		Incident	Count	6	0	2	6	14
			% within OCTYPE	42,9%	0,0%	14,3%	42,9%	100,0%
			% within REPTOTALB	25,0%	0,0%	8,0%	16,2%	9,9%
			% of Total	4,3%	0,0%	1,4%	4,3%	9,9%

Crosstab								
ORREG				REPTOTALB				Total
				≤ 2.500	≥ 24.000	10.001 - 24.000	2.501 - 10.000	
PA	OCTYPE	Serious incident	Count	2	0	1	4	7
			% within OCTYPE	28,6%	0,0%	14,3%	57,1%	100,0%
			% within REPTOTALB	8,3%	0,0%	4,0%	10,8%	5,0%
			% of Total	1,4%	0,0%	,7%	2,8%	5,0%
	Total		Count	24	55	25	37	141
			% within OCTYPE	17,0%	39,0%	17,7%	26,2%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	17,0%	39,0%	17,7%	26,2%	100,0%
Total	OCTYPE	Accident	Count	32	76	47	43	198
			% within OCTYPE	16,2%	38,4%	23,7%	21,7%	100,0%
			% within REPTOTALB	41,6%	96,2%	63,5%	58,1%	65,1%
			% of Total	10,5%	25,0%	15,5%	14,1%	65,1%
		Incident	Count	20	1	9	16	46
			% within OCTYPE	43,5%	2,2%	19,6%	34,8%	100,0%
			% within REPTOTALB	26,0%	1,3%	12,2%	21,6%	15,1%
			% of Total	6,6%	,3%	3,0%	5,3%	15,1%
		Serious incident	Count	25	2	18	15	60
			% within OCTYPE	41,7%	3,3%	30,0%	25,0%	100,0%
			% within REPTOTALB	32,5%	2,5%	24,3%	20,3%	19,7%
			% of Total	8,2%	,7%	5,9%	4,9%	19,7%
	Total		Count	77	79	74	74	304
			% within OCTYPE	25,3%	26,0%	24,3%	24,3%	100,0%
			% within REPTOTALB	100,0%	100,0%	100,0%	100,0%	100,0%
			% of Total	25,3%	26,0%	24,3%	24,3%	100,0%

Note. Certain abbreviations are used in the statistical computation: APAC is Asia Pacific; EUR is Europe; PA is Pan America; ORREG stands for region of origin; OCTYPE stands for statutory occurrence classification; REPORTOTALB stands for the word classification of safety investigation reports.

Appendix IX *Chi-square test for occurrence classes, report length and accident control classes*

Crosstab						
OCTYPE				CONTROL		Total
				Controlled	Uncontrolled	
Accident	REPTOTALB	≤ 2.500	Count	16	11	27
			% within REPTOTALB	59,3%	40,7%	100,0%
			% within CONTROL	14,0%	18,0%	15,4%
			% of Total	9,1%	6,3%	15,4%
		≥ 24.000	Count	51	14	65
			% within REPTOTALB	78,5%	21,5%	100,0%
			% within CONTROL	44,7%	23,0%	37,1%
			% of Total	29,1%	8,0%	37,1%
		10.001 - 24.000	Count	25	19	44
			% within REPTOTALB	56,8%	43,2%	100,0%
			% within CONTROL	21,9%	31,1%	25,1%
			% of Total	14,3%	10,9%	25,1%
		2.501 - 10.000	Count	22	17	39
			% within REPTOTALB	56,4%	43,6%	100,0%
			% within CONTROL	19,3%	27,9%	22,3%
				12,6%	9,7%	22,3%
	Total		Count	114	61	175
			% within REPTOTALB	65,1%	34,9%	100,0%
			% within CONTROL	100,0%	100,0%	100,0%
			% of Total	65,1%	34,9%	100,0%
Incident	REPTOTALB	≤ 2.500	Count	8	2	10
			% within REPTOTALB	80,0%	20,0%	100,0%
			% within CONTROL	40,0%	66,7%	43,5%
			% of Total	34,8%	8,7%	43,5%
		≥ 24.000	Count	1	0	1
			% within REPTOTALB	100,0%	0,0%	100,0%
			% within CONTROL	5,0%	0,0%	4,3%
			% of Total	4,3%	0,0%	4,3%
		10.001 - 24.000	Count	5	0	5
			% within REPTOTALB	100,0%	0,0%	100,0%
			% within CONTROL	25,0%	0,0%	21,7%
			% of Total	21,7%	0,0%	21,7%
		2.501 - 10.000	Count	6	1	7
			% within REPTOTALB	85,7%	14,3%	100,0%
			% within CONTROL	30,0%	33,3%	30,4%
				26,1%	4,3%	30,4%
	Total		Count	20	3	23
			% within REPTOTALB	87,0%	13,0%	100,0%
			% within CONTROL	100,0%	100,0%	100,0%
			% of Total	87,0%	13,0%	100,0%

Crosstab						
OCTYPE				CONTROL		Total
				Controlled	Uncontrolled	
Serious incident	REPTOTALB	≤ 2.500	Count	11	7	18
			% within REPTOTALB	61,1%	38,9%	100,0%
			% within CONTROL	39,3%	53,8%	43,9%
			% of Total	26,8%	17,1%	43,9%
		≥ 24.000	Count	1	0	1
			% within REPTOTALB	100,0%	0,0%	100,0%
			% within CONTROL	3,6%	0,0%	2,4%
			% of Total	2,4%	0,0%	2,4%
		10.001 - 24.000	Count	10	3	13
			% within REPTOTALB	76,9%	23,1%	100,0%
			% within CONTROL	35,7%	23,1%	31,7%
			% of Total	24,4%	7,3%	31,7%
		2.501 - 10.000	Count	6	3	9
			% within REPTOTALB	66,7%	33,3%	100,0%
			% within CONTROL	21,4%	23,1%	22,0%
				14,6%	7,3%	22,0%
	Total		Count	28	13	41
			% within REPTOTALB	68,3%	31,7%	100,0%
			% within CONTROL	100,0%	100,0%	100,0%
			% of Total	68,3%	31,7%	100,0%
Total	REPTOTALB	≤ 2.500	Count	35	20	55
			% within REPTOTALB	63,6%	36,4%	100,0%
			% within CONTROL	21,6%	26,0%	23,0%
			% of Total	14,6%	8,4%	23,0%
		≥ 24.000	Count	53	14	67
			% within REPTOTALB	79,1%	20,9%	100,0%
			% within CONTROL	32,7%	18,2%	28,0%
			% of Total	22,2%	5,9%	28,0%
		10.001 - 24.000	Count	40	22	62
			% within REPTOTALB	64,5%	35,5%	100,0%
			% within CONTROL	24,7%	28,6%	25,9%
			% of Total	16,7%	9,2%	25,9%
		2.501 - 10.000	Count	34	21	55
			% within REPTOTALB	61,8%	38,2%	100,0%
			% within CONTROL	21,0%	27,3%	23,0%
				14,2%	8,8%	23,0%
	Total		Count	162	77	239
			% within REPTOTALB	67,8%	32,2%	100,0%
			% within CONTROL	100,0%	100,0%	100,0%
			% of Total	67,8%	32,2%	100,0%

Note. Certain abbreviations are used in the statistical computation: OCTYPE stands for the statutory occurrence classification; REPORTOTALB stands for the word classification of safety investigation reports.

Appendix X *Chi-square test for occurrence classes, report length and control attempt effectiveness*

Crosstab						
OCTYPE				Outcome		Total
				Negative	Positive	
Accident	REPTOTALB	≤ 2.500	Count	6	11	17
			% within REPTOTALB	35,3%	64,7%	100,0%
			% within OUTCOME	9,8%	20,4%	14,8%
			% of Total	5,2%	9,6%	14,8%
		≥ 24.000	Count	34	17	51
			% within REPTOTALB	66,7%	33,3%	100,0%
			% within OUTCOME	55,7%	31,5%	44,3%
			% of Total	29,6%	14,8%	44,3%
		10.001 - 24.000	Count	13	12	25
			% within REPTOTALB	52,0%	48,0%	100,0%
			% within OUTCOME	21,3%	22,2%	21,7%
			% of Total	11,3%	10,4%	21,7%
		2.501 - 10.000	Count	8	14	22
			% within REPTOTALB	36,4%	63,6%	100,0%
			% within OUTCOME	13,1%	25,9%	19,1%
			% of Total	7,0%	12,2%	19,1%
	Total		Count	61	54	115
			% within REPTOTALB	53,0%	47,0%	100,0%
			% within OUTCOME	100,0%	100,0%	100,0%
			% of Total	53,0%	47,0%	100,0%
Incident	REPTOTALB	≤ 2.500	Count	0	8	8
			% within REPTOTALB	0,0%	100,0%	100,0%
			% within OUTCOME	0,0%	47,1%	40,0%
			% of Total	0,0%	40,0%	40,0%
		≥ 24.000	Count	0	1	1
			% within REPTOTALB	0,0%	100,0%	100,0%
			% within OUTCOME	0,0%	5,9%	5,0%
			% of Total	0,0%	5,0%	5,0%
		10.001 - 24.000	Count	1	4	5
			% within REPTOTALB	20,0%	80,0%	100,0%
			% within OUTCOME	33,3%	23,5%	25,0%
			% of Total	5,0%	20,0%	25,0%
		2.501 - 10.000	Count	2	4	6
			% within REPTOTALB	33,3%	66,7%	100,0%
			% within OUTCOME	66,7%	23,5%	30,0%
			% of Total	10,0%	20,0%	30,0%
	Total		Count	3	17	20
			% within REPTOTALB	15,0%	85,0%	100,0%
			% within OUTCOME	100,0%	100,0%	100,0%
			% of Total	15,0%	85,0%	100,0%

Crosstab						
OCTYPE				Outcome		Total
				Negative	Positive	
Serious incident	REPTOTALB	≤ 2.500	Count	0	11	11
			% within REPTOTALB	0,0%	100,0%	100,0%
			% within OUTCOME	0,0%	47,8%	39,3%
			% of Total	0,0%	39,3%	39,3%
		≥ 24.000	Count	0	1	1
			% within REPTOTALB	0,0%	100,0%	100,0%
			% within OUTCOME	0,0%	4,3%	3,6%
			% of Total	0,0%	3,6%	3,6%
		10.001 - 24.000	Count	3	7	10
			% within REPTOTALB	30,0%	70,0%	100,0%
			% within OUTCOME	60,0%	30,4%	35,7%
			% of Total	10,7%	25,0%	35,7%
		2.501 - 10.000	Count	2	4	6
			% within REPTOTALB	33,3%	66,7%	100,0%
			% within OUTCOME	40,0%	17,4%	21,4%
			% of Total	7,1%	14,3%	21,4%
	Total		Count	5	23	28
			% within REPTOTALB	17,9%	82,1%	100,0%
			% within OUTCOME	100,0%	100,0%	100,0%
			% of Total	17,9%	82,1%	100,0%
Total	REPTOTALB	≤ 2.500	Count	6	30	36
			% within REPTOTALB	16,7%	83,3%	100,0%
			% within OUTCOME	8,7%	31,9%	22,1%
			% of Total	3,7%	18,4%	22,1%
		≥ 24.000	Count	34	19	53
			% within REPTOTALB	64,2%	35,8%	100,0%
			% within OUTCOME	49,3%	20,2%	32,5%
			% of Total	20,9%	11,7%	32,5%
		10.001 - 24.000	Count	17	23	40
			% within REPTOTALB	42,5%	57,5%	100,0%
			% within OUTCOME	24,6%	24,5%	24,5%
			% of Total	10,4%	14,1%	24,5%
		2.501 - 10.000	Count	12	22	34
			% within REPTOTALB	35,3%	64,7%	100,0%
			% within OUTCOME	17,4%	23,4%	20,9%
			% of Total	7,4%	13,5%	20,9%
	Total		Count	69	94	163
			% within REPTOTALB	42,3%	57,7%	100,0%
			% within OUTCOME	100,0%	100,0%	100,0%
			% of Total	42,3%	57,7%	100,0%

Note. Certain abbreviations are used in the statistical computation: OCTYPE stands for the statutory occurrence classification; REPORTOTALB stands for the word classification of safety investigation reports.

Appendix XI *Chi-square test for occurrence classes and recommendations for control attempt effectiveness*

Crosstab						
OCTYPE				Outcome		Total
				Negative	Positive	
Accident	REPRECNB	≥ 7	Count	31	18	49
			% within REPRECNB	63,3%	36,7%	100,0%
			% within OUTCOME	50,8%	33,3%	42,6%
			% of Total	27,0%	15,7%	42,6%
		0	Count	9	28	37
			% within REPRECNB	24,3%	75,7%	100,0%
			% within OUTCOME	14,8%	51,9%	32,2%
			% of Total	7,8%	24,3%	32,2%
		1 - 6	Count	21	8	29
			% within REPRECNB	72,4%	27,6%	100,0%
			% within OUTCOME	34,4%	14,8%	25,2%
			% of Total	18,3%	7,0%	25,2%
	Total		Count	61	54	115
			% within REPRECNB	53,0%	47,0%	100,0%
			% within OUTCOME	100,0%	100,0%	100,0%
			% of Total	53,0%	47,0%	100,0%
Incident	REPRECNB	0	Count	0	11	11
			% within REPRECNB	0,0%	100,0%	100,0%
			% within OUTCOME	0,0%	64,7%	55,0%
			% of Total	0,0%	55,0%	55,0%
		1 - 6	Count	3	6	9
			% within REPRECNB	33,3%	66,7%	100,0%
			% within OUTCOME	100,0%	35,3%	45,0%
			% of Total	15,0%	30,0%	45,0%
	Total		Count	3	17	20
			% within REPRECNB	15,0%	85,0%	100,0%
			% within OUTCOME	100,0%	100,0%	100,0%
			% of Total	15,0%	85,0%	100,0%

Crosstab						
OCTYPE				Outcome		Total
				Negative	Positive	
Serious incident	REPRECNB	≥ 7	Count	0	2	2
			% within REPRECNB	0,0%	100,0%	100,0%
			% within OUTCOME	0,0%	8,7%	7,1%
			% of Total	0,0%	7,1%	7,1%
		0	Count	2	12	14
			% within REPRECNB	14,3%	85,7%	100,0%
			% within OUTCOME	40,0%	52,2%	50,0%
			% of Total	7,1%	42,9%	50,0%
		1 - 6	Count	3	9	12
			% within REPRECNB	25,0%	75,0%	100,0%
			% within OUTCOME	60,0%	39,1%	42,9%
			% of Total	10,7%	32,1%	42,9%
	Total		Count	5	23	28
			% within REPRECNB	17,9%	82,1%	100,0%
			% within OUTCOME	100,0%	100,0%	100,0%
			% of Total	17,9%	82,1%	100,0%
Total	REPRECNB	≥ 7	Count	31	20	51
			% within REPRECNB	60,8%	39,2%	100,0%
			% within OUTCOME	44,9%	21,3%	31,3%
			% of Total	19,0%	12,3%	31,3%
		0	Count	11	51	62
			% within REPRECNB	17,7%	82,3%	100,0%
			% within OUTCOME	15,9%	54,3%	38,0%
			% of Total	6,7%	31,3%	38,0%
		1 - 6	Count	27	23	50
			% within REPRECNB	54,0%	46,0%	100,0%
			% within OUTCOME	39,1%	24,5%	30,7%
			% of Total	16,6%	14,1%	30,7%
	Total		Count	69	94	163
			% within REPRECNB	42,3%	57,7%	100,0%
			% within OUTCOME	100,0%	100,0%	100,0%
			% of Total	42,3%	57,7%	100,0%

Note. Certain abbreviations are used in the statistical computation: OCTYPE stands for the statutory occurrence classification; REPRECNB stands for the number of published safety recommendations in safety investigation reports.