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This paper reports results from a survey-based study among eighty-six airline pilots investigating their willingness to report safety-relevant events and incidents. Pilots have been asked to report how many events they have experienced in thirty-five different contextual areas and how often they have reported these cases. Thus, underreporting rates, respectively dark figures, were calculated and listed. These results and the willingness to report are discussed within an aviation operation's background. Most of these surveyed underreporting rates are very high, which means a substantial source of uncertainty in airlines' safety reporting databases, and thus for airlines' safety management systems.

In safety-critical domains like the nuclear, intensive healthcare or aviation industry, reporting systems play an important role in safety management: as *to err is human*, error reports are crucial to learning from errors and avoiding future errors. A well accepted reporting culture supports this process. It is often unclear, however, whether the willingness to report observed or self-committed errors is distinctive or not (Tani, 2010). Underreporting, or dark figures, means that safety-critical events occur and are observed by operators, however, are not being reported to superiors, safety departments or authorities. These dark figures are frequently rather high and unknown due to the fear of being blamed for committed errors in professional life. Heinrich (1931) carried out studies about occupational safety and health. He proposed that in a workplace, for every accident that causes a major injury, there are 29 accidents with minor injuries and 300 accidents with no injuries - named as incidents or *near misses* (1-29-300). The detailed analysis of such a large number of incidents could prevent accidents because they share common root causes. With a further investigation of more than 1.5 million reported events reported by 297 cooperating companies, Bird and Germain (1985) determined that the number of *near misses* is even greater than once thought. They revised the ratio of one accident (with a serious or major injury) to ten occurrences with minor injuries to 30 property damage incidents up to six hundred *near-miss* incidents with no visible damage (1-10-30-600). Illustrated as the *iceberg model*, the works of Heinrich, Bird, and Germain expose that accidents, serious incidents or property damage only represent the small visible part above the water surface. An occurrence reporting system allows companies to gather larger quantities of incident information by individuals. Detailed analysis of the data allows a look beneath the water surface of the *iceberg model.* Related safety precautions derived from this data could prevent accidents, but only if the incidents are reliably and truthfully reported by the individuals.

There is much literature about incident reporting in general; however, precise domain-specific under-reporting rates, respectively dark figures, are rarely published. Factors influencing incident reporting, like a manager's reactions to reports, were found in literature and discussed by Clarke (1998). She also conducted an experiment among train drivers to find out reasons for not reporting. Her main finding indicates that the managers' reactions to reports play an important role on operators' willingness to report. Pransky, Snyder, Dembe, and Himmelstein (1999) have reviewed literature about underreporting of work-related disorders and collected data about unreported wrist/hand symptoms: 53% of these have not been reported. Reasons for underreporting were the fear of consequences on the job and disciplinary actions, or only minor symptoms. Four factors influencing underreporting were derived from literature by van der Schaaf and Kanse (2004): the fear for disciplinary action, an attitude of risk acceptance, a feeling of uselessness of reporting, and several practical reasons. Tani (2010) listed reporting schemes and systems in aviation from several countries in her thesis. Her research questions addressed different aspects of the use of these tools, and in the empirical part of her work she figured out six factors affecting the willingness to report: seriousness of errors, direct or indirect involvement in errors, working environment, legal protection of the reporter, motive of the wrongdoer, and relationship to the wrongdoer (Tani, 2010). Knowing these factors can help an organization to establish a reporting system or to improve the willingness to report. One

important issue about reporting in general is postulated by Strauss (2002): reports are always processed and evaluated by technical staff with shifting focus. Some reports were written and submitted, but were sorted out and so this number biases underreporting. When looking for precise numbers of underreporting, most sources deliver crime or medical data; only few works have been published in transportation. Jayasuriya and Anandaciva (1995) have conducted an experiment to evaluate compliance in reporting systems in anesthesia and found a dark figure of 70%. Barach and Small (2000) mentioned dark figures in medicine between 50% and 96% for adverse events in the U.S. They also deliver a descriptive list of non-medical incident reporting systems and a list of barriers and incentives for reporting. For underreporting of aviation wirestrikes in Australia, a dark figure of 40% can be found (ATSB, 2012). An estimated dark figure of 20% for birdstrike reporting in the U.S. is given by Cleary, Dolbeer, and Wright (2000). For maritime tanker operations, Psarros, Skjong, and Eide (2010), deliver dark figures of at least 59% and 70%, depending on the data source. To our knowledge there is no publication dealing with situation- or task-specific underreporting in aviation. Literature and experience from practice offer a differentiated insight into an aviation industry, which is highly cost driven, strongly influenced by international competition and focused on a constant increase of productivity, sometimes neglecting safety.

Method

Research Question

The research question of this paper is about the underreporting rate of incidents from airline pilots during their daily flight operation: how many events and incidents do pilots report to their safety department in relation to the total amounts of experienced incidents? In addition a subsequent research question is whether there are specific types of events and incidents showing higher underreporting than others. The research question cannot be answered with the help of any other database. German aviation accidents and severe incidents are defined by law (FlUUG of 1998, 1998); they have to be reported by national regulation (LuftVO of 1963, § 5, 2012) to the German Federal Bureau of Aircraft Accident Investigation (BFU) and by European Commission Regulation (EU) No 965/2012 via the German Federal Aviation Office (LBA) into a database. Even though an underreporting is assumed not to appear, any official database is just the sum of the individual databases of the different airlines.

Questionnaire

The focus of this survey was to ask pilots about the number of events and incidents they have experienced (m) in the last twelve months prior to the experiment and, in a second question, the number of events they have reported (n). The under-reporting rate (Probst & Estrada, 2010), respectively the dark figure, is then calculated as follows: *dark figure = (1- n/m)*. To specify the severity of experienced events, four different categories were defined (Table 1). There was not only one question for such events, but 35 questions divided into three different thematic areas: ground operations, in-flight operations, and human factors. All questions can be seen in Table 2.

Table 1.

Four succeeding severity categories for experienced events and incidents.

Category	Description: A safety-relevant event …
A	whose consequences were completely covered by the crew (*'problem was solved'*)
B	whose consequences were only partly covered by the crew (*'that was close'*)
C	whose consequences were not covered by the crew (*'by a whisker'*)
D	where the situation was completely out of control *('oh my gosh')*

Participants

The participants of this survey were scheduled for a non-voluntary full-flight simulator research experiment (Haslbeck, Gontar, & Schubert, 2014). They work as pilots for the same airline, either on an Airbus A320 short-haul or an Airbus A340 long-haul fleet. From altogether one-hundred-twenty pilots, eighty-six pilots participated in this survey on an anonymous basis during their waiting time for the experiment. Thirty-four participants can be assigned

to the group of A320s (15 CPT, 19 FOs) and thirty-five can be assigned to the group of A340s (16 CPTs, 19 FOs). With six female participants (five FOs and one CPT), the group very well represents partner airline proportions at approximately five percent.

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Results

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Data Analysis

To calculate a dark figure, all events of one contextual-category are added and compared to the number of reports afterwards according to the abovementioned formula. When analyzing the obtained data from pilots, the values given in category A show a remarkably higher variability compared to the other three categories. In theory, someone might expect very high numbers in category A and, the more severe the categories become, constantly falling numbers, like postulated by Heinrich (1931). However, there are at least two different types of entries in category A: some pilots have mentioned up to 1,000 events for deviations from standard operating procedures (SOP), while other pilots mentioned no such events in the same category at all. From their personal perspective, both might be right: one pilot calculates 20 flights per month (on short-haul operation), 10 working months per year, and roughly estimates 5 SOP deviations per flight – another pilot notices no SOP deviations at all. These differing perceptions might be the cause of a lower reliability of data in category A. Another question considering this category must be discussed: even when these events need to be reported in theory, it can be disbelieved whether such category A occurrences will be reported and, in addition, whether these occurrences will be added to the database, as Strauss (2002) postulated his doubts. Because of these limitations concerning category A, two different methods to calculate the dark figures were applied. In one calculation, representing a lower boundary, only the numbers of categories B, C, and D were added (method 1); in another approach, representing an upper boundary, all four categories have been taken into account (method 2). The data analysis also allows the identification of the highest risks within the flight operation. These incidents with frequent D-categorized occurrences are marked in bold letters. The calculated dark figures for safety-relevant events as described in the above paragraph are shown in Table 2.

Table 2.

Dark figures for safety-relevant events as reported by 86 commercial airline pilots.

Description	Method 1 (B+C+D)		Method 2 (A+B+C+D)	
	number of entries	calculated dark figure	number of entries	calculated dark figure
deviations from SOPs (procedures, callouts, wording, etc.)	140	.971	2707	.999
complacency (airborne use of cell phone/laptop, reading, programming of FMA too late, distraction below FL100)	142	.993	2664	1.0
time pressure induced by organizational deficits (ground handling, turn-around, dispatch, technical condition of aircraft, etc.)	**376**	**.939**	**1577**	**.985**
errors due to external factors on ground (time pressure, difficulties due to operational reasons, e.g. the technical status of the aircraft.)	108	.852	840	.981
reduced capability (fatigue, illness, stress)	**338**	**.962**	**687**	**.981**
ATC-induced time pressure (start-up, slot, parking position, push-back)	82	.963	610	.995
weather induced problems airborne (fog, visibility, turbulence, thunderstorm, icing, wind, lightning, etc.)	**70**	**.814**	**513**	**.975**
problems with paper-based documentation (flight plan, fuel calculation, NOTAMS, weather, technical, HIL)	48	.854	489	.986
neg. operational factors at the airport (ATC language problems, airport closures, congestion, FODs, birds, etc.)	95	.821	457	.963
clear and organized arrangement of the airport (taxiways, signs, etc.)	102	.961	397	.99

weather induced problems on ground (contamination, wind, gusts, fog, rain, RVR or visibility)	44	.909	303	.987
problems with electronic documentation (LIDO, EFB, eRoute Manual, performance calculation, OM A - C)	42	.738	291	.962
autoflight system (A/P and F/D-modes, ILS-capture, lat. and vert. control, manual handling, mis-selection, etc.)	30	.933	288	.993
incorrect inputs on the FMS (route, flight plan, arrival, departure)	25	.8	184	.973
incorrect take-off data or performance calculation	25	1.0	156	1.0
birdstrike	36	N/A	123	.455
smell in cabin	9	N/A	127	.858
unruly passengers	24	.167	108	.815
unstabilized approach (no go-around performed)	32	.969	103	.99
low fuel due to OPS, economic considerations, weather, etc.	26	.846	76	.947
smell on flight deck	15	.4	70	.871
unintended deviation from flight path on heading or altitude	18	.944	45	.978
lack of flight training, lack of manual practice, manual flying	20	.95	42	.976
loss of control (unusual attitudes, early flap retraction, overspeed, turbulence, IR or IAS disagreements, etc.)	6	.5	37	.919
incorrect weight and balance loadsheet	6	.833	36	.972
loss of separation with other aircraft	12	.25	34	.735
insufficient / inaccurate de-icing	9	.556	24	.833
near-miss on ground (with other aircraft, ground vehicle, people, lamp pole, ground power, etc.)	**9**	**.333**	**18**	**.667**
hard landing	4	.000	17	.765
flight crew incapacitation	3	1.0	10	1.0
visible smoke on flight deck or in cabin	3	N/A	5	.2
taxiway and apron excursion	2	.5	4	.75
landing with fuel for less than 30 mins.	**2**	**1.0**	**2**	**1.0**
runway incursion	1	.000	1	.000
RWY excursion at the end or on the side	1	.000	1	.000

Discussion

Reasons for Underreporting

Pilots were asked if their reporting had changed within the last ten years. Exactly 50% of the pilots said their amount of written air safety reports did not change, 47% stated they write less reports, and only 3% write more reports compared to 10 years age. The reasons for not writing air safety reports differ significantly between short and long haul pilots. For short haul pilots, it is the complexity of writing a report with a complicated and time-consuming database software. Thereafter, it is the negative feedback by their superior and third, the lack to initiate change. On the contrary, for long haul pilots, it is first the negative feedback by their superiors and then the lack to initiate change. The third reason for not writing is the generally felt meaninglessness and insignificance of any air safety report. Moreover, the events above can be clustered into different contextual accident and incident categories: organization (ORG), environmental (ENV) threats, technical failures (TEC), and human (HUM) performance issues.

Organizational Challenges

With this survey, it also became possible to identify the five most severe events (D category), representing the highest risks. The first two are *time pressure induced by organizational deficits* (ground handling, turn-around, dispatch, technical condition, etc.) and *reduced capability* (fatigue, illness, stress). Both event types may be mitigated by measures and changes, taken by one's own organization like ground handling or crew scheduling. Competition in business and permanent cost pressure continuously lead to longer duty times and an increased workload with less time for recreation. Furthermore, every airline aims to shorten the time span for airplanes standing on ground. And every airline is interested in minimizing the amount of personnel involved. For the future, it is a challenge for company leadership to keep the balance between continuously improving the existing processes and at the same time, minimizing organizational deficiencies. Frequent irregularities and operational difficulties like delays or technical problems of the airplane have to be considered. Understandably, the deviations from the standard operation procedures lead to a higher workload and increased time pressure, which again lead to an increase in errors and incidents. The results illustrate that operational difficulties put significant stress on pilots who seem to be unprepared and untrained for handling these organizational difficulties. In support of the international accident statistic, todays training of flight crews is mainly focused on flight safety regarding the handling of abnormal situations in-flight. In the future, crew training should be expanded to practice organizational difficulties on ground. This approach intends to help crews to cope with these changes and lead to more efficient organizational circumstances during ground operation.

Other high-risk D-categorized events imply *weather induced problems in the air*, being *low on fuel* and *near-miss on ground* (with other aircraft, ground vehicle, people, lamp pole, ground power, etc.). It may be assumed that there is a correlation between *bad weather* and *being low on fuel*. Ending up with minimum fuel during bad weather could be a planning deficiency by the crew, but could also be the consequence of economic pressure within the airline. It could well be the organization trying to make the crew take less fuel than practicable. The management of an airline is able to counteract both risks. Offering better weather information in combination with additional fuel on board could be a simple answer to the problem. It might even be reasonable for an airline to dictate minimum fuel values for certain weather phenomena, giving flight crews more time to deal with hazardous weather situations during flight.

It may be assumed that underreporting is more severe among low cost airlines. They frequently employ pilots via employment agencies (Bachman & Matlack, 2015). Staff members become *self-employed-pilots* which imply weaker pilots' labor rights. Their fixed-term contracts do not include permanent positions. A pilot's safety report criticizing organizational deficiencies including the superiors would not only be unpopular, but could also have consequences for the continuation of a pilot's labor contract.

Safety Management

According to ICAO Doc 9859 (ICAO, 2009), there are many approaches to risk assessment. Each time when evaluating a risk, both the probability of occurrence of a hazardous effect and the severity potential of that effect need to be taken into account. It is a common practice to use a risk classification matrix in support of this two-dimensional judgment. To know the probability, safety management does need information about the actual number of incidents within their operation. The underreporting shown in this survey is too extensive to give a reliable base for such an approach like the risk matrix. The survey pointed out substantial underreporting among human factor issues like SOP deviations or fatigue. Risks due to fatigue could, therefore, be underestimated, whereas technical risks with lower underreporting rates, like mid-air-collisions, could be overestimated. Prospective safety work should try to estimate the amount of occurrences. Regular and anonymous surveys among employees of airlines could be an additional possible and suitable approach for the future.

Air transportation will continue its growth. To keep today's accident rates low, it is necessary to further improve flight safety. For staying successful, airline management must continue optimizing its organizational structures, and they must simultaneously utilize all available safety information to avoid and reduce risks. This balance will be trendsetting and a key item for the long-term success of an airline. This survey has shown that existing reporting systems alone are no longer able to gather important safety data. In today's airline industry, additional means to collect data must be implemented.

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